

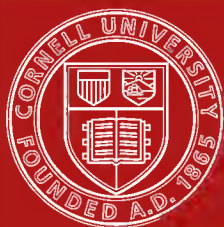
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IMPERIAL MINERAL RESOURCES BUREAU.

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# THE MINERAL INDUSTRY OF THE BRITISH EMPIRE

AND

## FOREIGN COUNTRIES.

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**WAR PERIOD.**

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# COPPER.

(1913-1919.)



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# PREFACE

The following digest of statistical and technical information relative to the production, consumption and value of copper will form a part of the volume or volumes on the Mineral Resources of the British Empire and Foreign Countries constituting the Mineral Conspectus of the Bureau.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included. Resort will also be had to graphical representation of statistics of production, consumption, costs, and prices.

The weights are expressed in long tons, that is to say, the British statute ton of 2,240 lb., and values in pounds, shillings and pence at par rates of exchange.

Dr. F. H. Hatch, a Governor of the Imperial Mineral Resources Bureau, is Chairman of the Advisory Technical Committee which has revised this work.

(Signed) R. A. S. REDMAYNE,

*Chairman of the Governors.*

2, Queen Anne's Gate Buildings,

London, S.W.1.

January, 1922.

B880 539

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## GENERAL

## COPPER ORES

The minerals containing copper are very numerous, but only a few of them are sufficiently abundant to serve as ores of copper. The more important are as follows:—

			<i>Composition.</i>	<i>Copper Percentage.</i>
Native copper	...	...	Cu	100
Chalcopyrite	...	...	$\text{Cu}_2\text{S} \cdot \text{Fe}_2\text{S}_3$	34.5
Bornite or erubescite	...	...	$3\text{Cu}_2\text{S} \cdot \text{Fe}_2\text{S}_3$	55.5
Chalcocite or copper-glance	...	...	$\text{Cu}_2\text{S}$	79.8
Covellite	...	...	CuS	66.4
Enargite	...	...	$3\text{Cu}_2\text{S} \cdot \text{As}_2\text{S}_5$	48.3
Tennantite	...	...	$3\text{Cu}_2\text{S} \cdot \text{As}_2\text{S}_3$	52.5
Tetrahedrite	...	...	$3\text{Cu}_2\text{S} \cdot \text{Sb}_2\text{S}_3$	52.1
Cuprite	...	...	$\text{Cu}_2\text{O}$	88.8
Melaconite (tenorite)	...	...	CuO	79.8
Malachite	...	...	$\text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3$	57.5
Azurite	...	...	$\text{Cu}(\text{OH})_2 \cdot 2\text{CuCO}_3$	55.3
Chrysocolla	...	...	$\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$	36.0–40.0
Brochantite	...	...	$\text{CuSO}_4 \cdot 3\text{Cu}(\text{OH})_2$	56.2
Chalcanthite	...	...	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	25.4
Cupreous iron-pyrites	...	...	—	up to 5

Of these minerals chalcopyrite represents the chief primary ore from which, directly or indirectly, the others have mostly been derived. It occurs generally as a low-grade ore which usually requires considerable treatment before a marketable product is obtained. Some of the other minerals, notably chalcocite and copper carbonates, occur in richer deposits which have been already concentrated by natural chemical changes. These secondary deposits yield valuable ore, from which large supplies of metal can be recovered cheaply, but the "zone of secondary enrichment" tends to give way to the leaner primary ores as mines get deeper. It is important to realize that these enriched deposits have yielded in the past a large part of the world's production and that the maintenance of a supply of cheap copper will depend in large measure on the discovery of new areas of such enriched deposits, which are most likely to be found in regions of small rainfall, particularly in tropical countries.

Fortunately there are many parts of the globe that have not yet been prospected. Large tracts of Africa, northern and eastern Asia, and south and central America, have scarcely been explored, and it can hardly be doubted that a thorough examination of these regions would yield important discoveries of copper deposits.

## USES.

The use of copper dates from the Bronze Age, when, hardened by alloying with tin, it was the chosen material for weapons and cutting implements. The beauty of its colour gave it a place in Art, and the ease with which it can be worked has led to its employment for many domestic and industrial purposes. For household use it has been displaced to some extent by aluminium and enamelled steel, but large quantities of copper are shipped as rolled sheets to eastern countries, where copper or brass are still almost the only materials from which domestic utensils are made.

Besides being very malleable and capable of taking a high polish, copper is an excellent conductor of heat and electricity and is, therefore, of value for a great variety of purposes.

The largest and most increasing demand is for electrical use.—such as for cables and wires for transmission of current and for telegraphs and telephones, parts of dynamos, motors and other apparatus—while among its other more important uses are steam and hydraulic pipes, sugar pans and coolers, locomotive boiler tubes, fire box plates and rods, brewing and distilling appliances, plates for engraving and process printing, rollers for calico printing, tubes, sheets, wire, etc., for general coppersmiths' work. For sheathing wooden ships there was formerly a large demand, which has fallen away owing to steel having taken the place of wood in naval construction.

One of the most important uses of copper is in alloy with zinc as brass, which either as castings or worked in sheets, tubes or wire, is seen in nearly every article of daily use, from a pin or a door handle to a motor car or an Atlantic liner.

Among the best-known alloys of the brass type are the ductile brasses, such as cartridge metal (copper 70, zinc 30), the ordinary cast or rolled brasses (about 65 copper, 35 zinc), Muntz metal (60 : 40), extruded metal (58 : 42), and brass solders (50 : 50). Delta metal and "manganese bronze" are examples of high tensile brasses with about 60 per cent. of copper and iron or manganese.

The copper alloys of industrial importance may conveniently be divided into the following classes :—

*Copper and Zinc*, forming the brasses already alluded to and containing 50 to 70 per cent. of copper.

*Copper and Tin*, forming a large class of alloys known generally as the bronzes used in engineering practice and for coinage, ordnance, and many other purposes. The composition of industrial bronze is very variable, many of the alloys containing other metals in addition to copper and tin. As a general rule the copper content in bronzes varies from 75 to 92 per cent.

*Copper and Nickel*.—Alloys of these two metals, which are known as cupro-nickel or cupro, usually contain 75 to 80 per cent. of copper and are used for bullet cases, &c. The most important

alloys of this class, however, are those consisting of copper, nickel and zinc, forming the so-called "nickel-silver" (sometimes called "German silver"). They are very variable in composition, but the best qualities usually contain from 50 to 62 per cent. of copper. These alloys appear under a great variety of special trade names, and are largely used as a basis metal for electroplate and for a variety of other purposes. Monel metal is an alloy made by the direct smelting of the copper-nickel ore found in the Sudbury district of Canada. Pure copper is not, therefore, utilized in its preparation.

*Copper and Aluminium.*—The alloy known as "duralumin," which contains from 3 to 5 per cent. of copper, has found extensive use for aeroplane and motor-car construction on account of its strength and elasticity. Useful alloys of copper with aluminium up to 10 per cent. are also produced.

The sub-oxide is employed for the production of a red glaze on pottery, and for copper enamels in jewellery and on porcelain; the silicon-copper alloy is used as a deoxidizer in bronzes.

Locomotive tubes, fire-box plates and stay rods are made almost exclusively of copper containing a small percentage (from 0.2 to 0.5) of arsenic. The effect of the arsenic is to increase the tensile strength and resistance to the erosive action of the products of combustion.

Other metals, such as antimony and bismuth, are often present as impurities in copper to the detriment of its mechanical properties. The effect of very small quantities can be neutralized by the amount of oxide left in the metal during the last stage of refining, an operation known as bringing to "tough pitch."

Copper sulphate, "blue vitriol" or "bluestone," is used in the manufacture of various pigments, such as "Brunswick green" and "Venetian red," but its principal use is for agricultural purposes as a fungicide. The "Salzburg vitriol" prepared at Buxweiler contains both iron and copper, and "Cyprian vitriol" prepared at Chessy is got from zinciferous copper-ores.

#### GRADES OF COPPER

The commercial grades of copper may be summarized as follows:—

*Lake copper* from the native copper of the mines in the Lake Superior district of the United States. This copper is exceptionally pure and possesses a high degree of conductivity.

*Electrolytic copper* refined by the electrolytic process and containing 99.9 per cent or more of the metal. It is made in cathodes, which are usually remelted and cast into ingots, ingot bars, cakes and wire bars.

*Best selected ingots* containing 99.5 to 99.75 per cent., used in the best brass trades.

*Casting ingots* containing 99 per cent. or more, used for the making of commoner brasses.

*Tough copper* contains about 99.25 to 99.5 per cent., and is made in ingots, cakes or other suitable shape, and used for casting, rolling and drawing.

*Blister copper* includes Chile bars and contains anything from 94 to 99 per cent., and in some cases carries bullion. Practically everything cast in bars within this range of copper contents, and capable of being refined by the fire process, forms to a large extent the basis of the dealings in Standard Copper on the London Metal Exchange.

The above grades are made in the following forms :—

*Wire Bars*.—About 3 to 4 inches square and 30 to 40 inches long, pointed or rounded at the ends. Average weight 135 to 140 lb.

*Ingots*.—Average weight about 18 to 24 lb. Notched. Used in casting.

*Ingot Bars*.—Notched bars used in casting. Weight about 45 to 80 lb.

*Cakes*.—Weight 112 lb. and upwards to 5,535 lb. Used for rolling in sheets and plates.

*Anodes*.—About 24 by 36 by  $1\frac{1}{2}$  inches, weighing 250 lb. Crude copper used by electrolytic refiners.

*Cathodes*.—About 36 by 18 by  $\frac{1}{2}$  to 1 inches. Refined copper from the electrolytic tanks.

*Slabs*.—Rough copper about 1 to 2 cwt. each, 28 by 19 by 2 inches.

## WORLD'S PRODUCTION AND CONSUMPTION.

The increase in the production of copper may be realized from the fact that the average annual production at the beginning of the nineteenth century was only about 9,000 tons. By the middle of the century the production had grown to about 40,000 tons, and about the end of the century it was over half-a-million tons. In 1913 the production was about 979,000 tons, and in 1918 it reached 1,387,000 tons.

During the war, the requirements of copper for munitions and other war purposes in the form of copper bands and brass fuses for shells, brass cartridges, cupro-nickel bullets, tubes for warships, cables and electrical equipment, &c., were so large as to leave little available for normal purposes in spite of a considerable increase in production; this increase was mainly from the United States, Canada, Chile, Peru, Japan, Africa and Germany. The production of Mexico and Russia showed a decrease as compared with their pre-war output.

*World's Production of Copper Ore (in terms of copper content)*  
(long tons)

—	1913	1914	1915	1916	1917	1918	1919
United Kingdom ...	421	341	235	278	187	179	144
Northern Rhodesia ...	†5,856	763	176	1,159	1,803	793	182
Southern Rhodesia ...	—	903	3,140	3,144	3,493	2,905	2,689
Union of South Africa	8,262	11,288	10,881	10,197	8,028	5,065	3,674
Canada ...	34,365	33,811	44,993	52,299	48,762	53,022	33,506
Newfoundland*	—	—	180	210	75	—	—
India* ...	143	200	333	100	751	136	1,228
Australia ...	46,493	38,426	39,978	38,807	39,429	38,358	19,183
France ...	31	11	10	40	54	23	2
Germany*	25,950	24,400	28,250	35,300	31,750	27,850	17,050
Greece ...	4	5	1	4	—	—	—
Italy ...	2,917	2,473	2,731	2,843	2,822	2,470	713
Norway ...	14,132	13,159	15,540	8,894	9,974	10,756	—
Portugal ...	5,387	4,250	3,231	2,331	1,848	1,101	905
Russia* ...	33,700	31,700	25,500	21,000	13,300	10,000	—
Spain ...	*47,300	30,606	31,076	33,121	44,812	17,621	62,256
Sweden ...	1,157	1,306	2,535	3,153	4,255	4,621	3,168
Algeria* ...	—	31	—	12	264	176	40
Belgian Congo ...	5,324	10,172	13,814	21,809	27,055	19,913	22,634
French Equatorial Africa.	502	639	244	291	75	—	—
Cuba ...	2,833	4,561	10,882	15,531	20,726	16,523	9,560
Mexico ...	51,747	26,193	20,272	27,954	50,127	69,072	51,432
United States ...	551,594	512,693	664,318	895,479	846,175	852,689	541,221
Argentina (exports) ...	186	—	25	104	—	137	—
Bolivia (exports) ...	3,641	3,897	8,006	8,623	10,375	8,048	9,195
Chile ...	41,586	43,947	51,500	70,143	100,879	105,196	78,301
Peru ...	27,330	26,655	34,169	42,386	44,450	43,700	38,600
Venezuela ...	—	358	588	1,156	2,911	2,046	185
China (exports of ingots and slabs).	124	109	2,683	33,619	41,060	2,661	545
Japan, Formosa and Korea.	66,835	71,049	75,524	99,969	109,307	92,301	†77,042
TOTAL ...	978,958	894,334	1,092,118	1,430,492	1,465,172	1,387,615	973,663

\* Estimated.

† From the commencement of operations to the end of 1913.

‡ Japan only.

NOTE.—In addition to the countries mentioned in the above table, copper ore has been produced in Austria and the Balkan States, but detailed statistics are not available.

Figures of consumption are not available for the war period, but the figures for 1913 are shown in the following table:—

*Copper Consumed in 1913*

(From : Metallgesellschaft, 1913)

	Quantity (long tons)
Europe :	
Germany ... ..	255,133
England ... ..	138,045
France ... ..	101,935
Austria-Hungary ... ..	38,570
Russia ... ..	39,554
Italy ... ..	30,698
Belgium ... ..	14,759
Netherlands ... ..	984
Other European Countries ... ..	13,086
Total Europe ... ..	632,764
America :	
United States ... ..	342,506
Other parts of America ... ..	2,952
Total America ... ..	345,458
Asia, Australia and Africa ... ..	49,491
World's Consumption ... ..	1,027,713

## PRICES

The most marked features in the course of prices of Standard Copper in London during the war period were the fall in value of copper from July, 1913, when the price was £64·166 per long ton, until November of the following year, when Standard Copper only realized £53·227 per ton ; its subsequent steady rise, up to December, 1915, when it stood at £80·773 per ton ; the sensational jump from the previous figure to £102·667 in February, 1916 ; a big drop to £95·119 in July, from which it recovered to £110·283 in August ; a continued rise till February, 1917, and then gradual decrease in value till, at the end of 1917, it reached about the same level as in August, 1916, viz., £110·000. During 1918, the price remained fairly steady, averaging £115·576, but at the end of the year a decline set in and continued until March, 1919, when the average was £76·879. Subsequently a rise took place, the average price for December, 1919, being £103·857, and for the whole year £90·945.

The average price per ton of "Best Selected" and "Foreign Copper" in the London Market from 1873 to 1919, at intervals of five years up to 1913 and each year subsequently, is shown in the following table:—

Year			Best Selected £	Foreign Copper £ (Burra Burra)
1873	...	...	95·900	92·275
1878	...	...	68·575	70·075
1883	...	...	69·162	68·725
				(Chile Bars)
1888	...	...	79·566	81·404
1893	...	...	48·195	43·816
1898	...	...	55·483	51·887
				(Standard)
1903	...	...	63·041	58·000
1908	...	...	63·791	59·962
1913	...	...	74·000	68·058
1914	...	...	66·329*	61·578
1915	...	...	82·666	72·637
1916	...	...	135·949	116·062
1917	...	...	134·444	125·120
1918	...	...	126·254	115·575
1919	...	...	98·444	90·966

\* Average of nine months. No quotations August to October, 1914.

The rise which took place during the war roughly represented the adjustment of prices to the demand and supply; the increased cost of production and freight; the rise of "exchange" in New York, as compared with London; and the depreciation of currency.

The markets of New York and London are the most important in the world: New York from the producer's, and London from the consumer's point of view.

*Official Monthly Average Prices of Copper*  
(Furnished by the London Metal Exchange)

Year and Month				Standard Copper	Best Selected Copper	Electrolytic Copper
<i>1913</i>				£ s. d.	£ s. d.	£ s. d.
January	...	...	...	71 18 5 $\frac{1}{2}$	78 1 8	77 18 3 $\frac{6}{11}$
February	...	...	...	65 12 4 $\frac{1}{2}$	71 16 3	71 8 3
March	...	...	...	65 8 9	70 16 3	69 5 6 $\frac{6}{15}$
April	...	...	...	68 4 9 $\frac{1}{2}$	74 5 0	71 15 2 $\frac{8}{11}$
May	...	...	...	68 18 9	75 0 5 $\frac{2}{5}$	72 12 4 $\frac{1}{4}$
June	...	...	...	65 4 5 $\frac{2}{5}$	71 3 9	69 6 9 $\frac{3}{7}$
July	...	...	...	64 5 10 $\frac{1}{3}$	69 14 5 $\frac{1}{3}$	67 10 0
August	...	...	...	69 6 0	74 3 10 $\frac{2}{3}$	72 11 9
September	...	...	...	73 5 3 $\frac{3}{2}$	78 16 1 $\frac{1}{3}$	76 19 10 $\frac{7}{11}$

*Official Monthly Average Prices of Copper—(Continued)*

Year and Month				Standard Copper	Best Selected Copper	Electrolytic Copper
				£ s. d.	£ s. d.	£ s. d.
<i>1913</i>						
October	...	...	...	73 9 $5\frac{1}{2}\frac{1}{3}$	78 18 4	77 8 $5\frac{1}{2}\frac{1}{3}$
November	...	...	...	68 8 9	73 12 6	72 0 6
December	...	...	...	65 5 $7\frac{1}{2}$	70 0 0	67 7 $4\frac{1}{2}$
<i>1914</i>						
January	...	...	...	64 7 $11\frac{5}{7}$	69 16 $1\frac{1}{3}$	66 17 $3\frac{1}{2}$
February	...	...	...	65 8 $5\frac{1}{2}$	70 8 9	67 15 9
March	...	...	...	64 8 $1\frac{1}{2}$	69 2 $9\frac{1}{3}$	66 10 $1\frac{1}{4}$
April	...	...	...	64 17 $4\frac{1}{2}$	69 9 $4\frac{1}{2}$	66 18 3
May	...	...	...	63 5 10	68 3 4	65 10 $1\frac{3}{4}$
June	...	...	...	61 9 $2\frac{5}{7}$	66 2 $2\frac{2}{3}$	64 0 $8\frac{1}{2}$
July	...	...	...	60 13 $0\frac{3}{2}\frac{2}{3}$	64 17 $2\frac{2}{3}$	62 10 $2\frac{1}{2}\frac{4}{3}$
August	...	...	...	no quotations	no quotations	no quotations
September	...	...	...	" "	" "	" "
October	...	...	...	" "	" "	" "
November	...	...	...	" 52 11 $2\frac{2}{7}$	" 57 1 $3$	" 54 18 $9\frac{5}{7}$
December	...	...	...	56 18 $4\frac{1}{2}\frac{1}{2}$	61 18 6	60 8 $2\frac{1}{2}\frac{1}{2}$
<i>1915</i>						
January	...	...	...	60 17 $7\frac{1}{2}$	65 14 $4\frac{1}{2}$	64 7 6
February	...	...	...	63 12 6	70 5 0	68 10 6
March	...	...	...	66 5 $5\frac{5}{2}\frac{5}{3}$	73 12 $2\frac{2}{3}$	72 5 $2\frac{1}{2}\frac{4}{3}$
April	...	...	...	75 3 $5\frac{1}{2}$	82 19 $5\frac{1}{3}$	81 12 9
May	...	...	...	77 14 3	87 13 9	87 14 6
June	...	...	...	82 13 $7\frac{7}{11}$	94 3 4	94 0 $10\frac{1}{2}\frac{1}{2}$
July	...	...	...	76 1 $11\frac{2}{11}$	89 0 $6\frac{2}{3}$	91 7 $8\frac{1}{11}$
August	...	...	...	68 15 $1\frac{1}{2}$	79 18 $10\frac{2}{3}$	82 6 $2\frac{2}{3}$
September	...	...	...	69 1 $1\frac{7}{11}$	79 3 9	85 6 $4\frac{1}{11}$
October	...	...	...	72 13 $6\frac{2}{7}$	87 7 $9\frac{1}{2}$	88 0 0
November	...	...	...	77 16 $9\frac{1}{11}$	93 13 4	93 8 $2\frac{1}{11}$
December	...	...	...	80 17 $10\frac{1}{11}$	99 7 $9\frac{1}{2}$	100 11 $4\frac{1}{11}$
<i>1916</i>						
January	...	...	...	88 2 11	112 17 6	116 3 $9\frac{2}{7}$
February	...	...	...	102 13 1	125 12 3	133 5 9
March	...	...	...	106 19 $10\frac{1}{3}\frac{2}{3}$	129 13 4	136 0 0
April	...	...	...	124 4 $0\frac{1}{3}$	133 17 6	137 10 $6\frac{2}{3}$
May	...	...	...	135 9 $10\frac{1}{3}\frac{2}{3}$	151 0 0	152 0 $10\frac{1}{3}\frac{2}{3}$
June	...	...	...	112 17 $8\frac{1}{11}$	137 13 4	137 9 $1\frac{1}{11}$
July	...	...	...	95 0 $8\frac{1}{7}$	122 18 9	125 8 $1\frac{1}{7}$
August	...	...	...	110 8 $3\frac{3}{2}\frac{3}{3}$	123 13 4	126 7 $9\frac{2}{3}\frac{1}{3}$
September	...	...	...	114 1 $5\frac{1}{7}$	130 15 $6\frac{2}{3}$	134 2 $4\frac{1}{7}$
October	...	...	...	122 10 0	144 4 $5\frac{1}{3}$	142 10 $10\frac{1}{2}\frac{1}{2}$
November	...	...	...	134 18 $2\frac{2}{11}$	156 7 6	154 11 $9\frac{1}{11}$
December	...	...	...	145 9 2	162 14 $5\frac{1}{2}$	160 18 $11\frac{1}{11}$
<i>1917</i>						
January	...	...	...	131 16 $8\frac{2}{3}\frac{2}{3}$	138 18 $10\frac{2}{3}$	141 1 $3\frac{1}{2}\frac{1}{3}$
February	...	...	...	138 5 9	144 6 3	146 8 6
March	...	...	...	137 1 $1\frac{7}{11}$	147 0 0	149 0 0
April	...	...	...	134 1 $10\frac{2}{9}\frac{2}{9}$	143 10 0	145 3 $1\frac{1}{9}\frac{1}{9}$
May	...	...	...	130 5 0	138 0 0	140 0 0
June	...	...	...	130 5 0	138 0 0	140 0 0
July	...	...	...	128 13 $2\frac{2}{11}$	136 6 8	138 8 $2\frac{2}{11}$
August	...	...	...	122 10 $5\frac{1}{11}$	133 0 0	135 0 0
September	...	...	...	117 15 0	131 5 0	133 5 0



*Official Monthly Average Prices of Copper—(Continued)*

Year and Month.				Standard Copper	Best Selected Copper	Electrolytic Copper
				£ s. d.	£ s. d.	£ s. d.
<b>1917</b>						
October	...	...	...	110 5 0	121 0 0	123 0 0
November	...	...	...	110 5 0	121 0 0	123 0 0
December	...	...	...	110 5 0	121 0 0	123 0 0
<b>1918</b>						
January	...	...	...	110 5 0	121 0 0	123 0 0
February	...	...	...	110 5 0	121 0 0	123 0 0
March	...	...	...	110 5 0	121 0 0	123 0 0
April	...	...	...	110 5 0	121 0 0	123 0 0
May	...	...	...	110 5 0	121 0 0	123 0 0
June	...	...	...	110 5 0	121 0 0	123 0 0
July	...	...	...	120 3 3 $\frac{3}{4}$	131 13 4	132 18 3 $\frac{3}{4}$
August	...	...	...	122 5 0	133 0 0	135 0 0
September	...	...	...	122 5 0	133 0 0	135 0 0
October	...	...	...	122 5 0	133 0 0	135 0 0
November	...	...	...	122 5 0	133 0 0	135 0 0
December	...	...	...	116 5 0	125 7 6	128 11 6 $\frac{1}{2}$
<b>1919</b>						
January	...	...	...	93 9 9 $\frac{3}{4}$	103 13 4	106 2 8 $\frac{1}{4}$
February	...	...	...	78 10 3	89 6 3	91 11 0
March	...	...	...	76 17 7 $\frac{3}{4}$	79 15 0	79 17 1 $\frac{5}{8}$
April	...	...	...	77 7 0	81 18 10 $\frac{2}{3}$	82 0 3
May	...	...	...	77 16 7 $\frac{1}{2}$	81 13 10 $\frac{2}{3}$	81 11 9 $\frac{3}{4}$
June	...	...	...	83 0 6	86 2 6	86 16 0
July	...	...	...	99 14 5 $\frac{1}{3}$	102 14 5 $\frac{1}{3}$	107 14 9 $\frac{3}{8}$
August	...	...	...	97 11 4 $\frac{1}{2}$	108 16 8	113 4 0
September	...	...	...	100 17 4 $\frac{7}{8}$	109 5 6 $\frac{2}{3}$	113 5 10 $\frac{1}{4}$
October	...	...	...	103 10 11 $\frac{1}{2}$	113 10 0	117 3 5 $\frac{1}{2}$
November	...	...	...	98 18 9	111 2 6	113 7 0
December	...	...	...	103 17 1 $\frac{1}{2}$	113 7 6	114 6 8

## BRITISH EMPIRE

### United Kingdom

The United Kingdom was a very important factor in copper production when the world's total output was but a fraction of what it is now. The maximum output was reached in 1860 with the production of 236,696 tons of copper ore, which yielded 15,968 tons of copper.

The chief producing mines were situated in Anglesea, Cornwall and Devonshire; but considerable quantities of ore were also obtained from County Wicklow, County Waterford, Bearhaven in the west of Ireland, and Alderley Edge in Cheshire.

The Caradon group of mines in the eastern division of Cornwall, Gwennap and Redruth in the western division, and Devon Great Consols in Devonshire, have all produced large quantities of copper ore, as also have the Levant mine (St. Just) and the mines of the Callington district.

In 1894, the Levant mine produced 1,882 tons of copper ore, representing about three-quarters of the output of the whole country.

There was little variation in production in Cornwall during the war period. Levant continued to be the chief producer, yielding 383 tons of copper-ore (containing 2,490 oz. of silver and 4 oz. of fine gold) in 1913.

The Parys and Mona mines in Anglesea at one time produced large quantities of copper ore (averaging from five to six per cent. of copper) and practically controlled the world's copper market but, although still yielding a substantial quantity of "copper precipitate" from the mine water, the mines are now closed. They are noteworthy as containing a deposit of complex ore ("blue-stone"), carrying about 2.13 per cent. copper, 28 per cent. zinc and 15 per cent. lead, which has never been utilized.

The chief producing mines in Wales during the war period have been the Britannia mine, Llanberis, Carnarvonshire, and the Glasdir mine, Dolgelly, Merionethshire.

All the copper ore won in Scotland during the war was obtained from the Otter mine in Argyllshire, a recently opened deposit on the eastern side of Loch Fyne.

The Sandlodge mine about 14 miles south of Lerwick in the Shetland Isles has been examined recently. The lode is a large one, but the copper content is low and the enriched portions near the surface, consisting of carbonates and silicates of copper associated with a spongy hæmatite, have been worked out. Below a depth of 100 feet the vein-filling consists of siderite, calcite, dolomite and quartz, through which cupreous pyrites is disseminated.

The Cronebane mine and the Tigroney and Baronets mines at Avoca, County Wicklow, in Ireland, produced 1,840 tons of cupreous pyrites, containing  $1\frac{1}{2}$  per cent. copper, in 1913, and continued producing during the war.

The exhaustion of several important deposits of copper in the west of England has not been due to the exhaustion of the lodes, but to an alteration in their metal contents, as at Dolcoath and Botallack, where copper was succeeded by tin in depth.

The largest copper deposits in Cornwall have always been in veins near to, but not actually in, granite, and chiefly in killas. According to Henwood, the copper lodes of Cornwall generally average about 3 feet in width; those yielding both tin and copper being wider and averaging  $4\frac{1}{2}$  feet. In Devonshire and Anglesea, the copper lodes were of much greater average width.

The veins at Devon Great Consols mine in the Tavistock district are found in a peculiar "spotted killas" and have been of comparatively low grade, rarely exceeding in recent times 4 per cent. on the average; but the lodes were from 20 to 40 feet

wide and carried a large quantity of arsenic, which was recovered. This mine still produces arsenic, as well as some copper precipitate.

Chalcopyrite, chalcocite, tetrahedrite and bornite are the most abundant copper minerals in Cornwall; but in the Caradon district rich red and black oxides, blue and green carbonates, and, more rarely, arsenates, phosphates, uranates, and native copper occur.

Some of the Welsh copper ores contain a little silver (5 to 6 oz. per ton) and  $\frac{1}{2}$  dwt. or more of gold; 900 oz. of fine gold and 10,526 oz. of silver were extracted from 2,373 tons of dressed copper ores produced in the United Kingdom in 1914.

According to the Home Office report for 1913, the copper content of Cornish ore ranged from 7 to  $13\frac{1}{2}$  per cent. In the Isle of Man it was 22·8 per cent., and in Scotland  $14\frac{1}{2}$  per cent. In Derbyshire, it amounted to only 4·7 per cent., while the average for Merionethshire is given as 10·0 per cent. In Ireland (Meath) the average was 10·7 per cent., but the iron-pyrites mined in the County of Wicklow carried only 1·2 per cent. of copper.

During the war period Cornwall produced, on the average, about 25 tons of copper precipitate, Devonshire 54 tons, and Anglesea 118 tons per annum.

The percentage of copper in this product varies considerably. In 1913 it averaged from 52·2 per cent. in Cornwall, to 69 per cent. in Devonshire, the percentage for Anglesea being calculated at 58 per cent.

While the production of copper from dressed ore and copper precipitate produced in the United Kingdom is comparatively small, and showed a tendency to decrease during the war period, the production of cupreous pyrites has nearly doubled in quantity since 1913.

Most of the metallic copper produced in the United Kingdom at the present time is obtained from imported cupreous iron pyrites and to a less extent from imported regulus and ores of copper. Many of the producing mines and works which supply these imports are largely owned or financed by British interests, being situated in Spain, South Africa and South America, where working conditions and rates of exchange have been favourable and less disturbed by the war than in other parts of the world.

Prior to the war the United Kingdom exported considerable quantities of sulphate of copper to foreign countries and British Possessions, chiefly to wine-growing countries.

*Production of Copper Ore and Copper Precipitate in the  
United Kingdom*

(Mines and Quarries, General Report, with Statistics, Part III,  
by the Chief Inspector of Mines).

Year	Dressed Copper Ore.		Copper Precipitate.	
	Quantity (long tons)	Estimated amount of copper obtainable (long tons)	Quantity (long tons)	Estimated amount of copper obtainable (long tons)
1913... ..	2,569	321	163	100
1914... ..	2,373	229	225	112
1915... ..	579	87	243	148
1916... ..	787	135	241	143
1917... ..	970	76	190	111
1918... ..	1,013	67	201	112
1919... ..	144	14	228	130

*Production and Imports of Iron-Pyrites in the United Kingdom*

(Mines and Quarries, General Report, with Statistics, Part III,  
by the Chief Inspector of Mines)

Year	Production Quantity (long tons)			Imports* Quantity (long tons)
1913 ... ..	...	...	11,427	781,711
1914 ... ..	...	...	11,654	803,149
1915 ... ..	...	...	10,535	903,467
1916 ... ..	...	...	10,481	949,996
1917 ... ..	...	...	8,515	854,241
1918 ... ..	...	...	22,195	836,703
1919 ... ..	...	...	7,336	344,457

\* Chiefly cupreous iron-pyrites. For details as to source of these imports, see p. 22.

Statistics regarding the treatment of burnt cupreous iron-pyrites at the metal extraction works in Great Britain since 1915 are not available. From 1913 to 1915, the details are as follows :—

Year	Pyrites treated (long tons)		Estimated extraction of metallic copper (long tons)
1913 ... ..	...	459,392	16,538
1914 ... ..	...	441,024	15,877
1915 ... ..	...	418,791	15,077

*Imports of Copper Ore into the United Kingdom*  
(Annual Statements of the Trade of the United Kingdom)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Rhodesia ... ..	1,021	1,104	673	120	1,009	300	1,795
Union of South Africa	5,841	12,735	12,063	13,746	7,981	1,721	508
India ... ..	351	465	1,105	—	—	—	—
Australia ... ..	13,284	13,998	3,895	2,526	7	—	—
Other British Possessions	1,035	117	3	242	—	—	2
<b>Total from British Possessions</b>	<b>21,532</b>	<b>28,419</b>	<b>17,739</b>	<b>16,634</b>	<b>8,997</b>	<b>2,021</b>	<b>2,305</b>
Belgium ... ..	1,135	1,805	—	—	—	—	—
France ... ..	2,443	1,138	584	601	158	90	880
Germany ... ..	1,017	1,245	—	—	—	—	—
Netherlands ... ..	133	—	—	—	—	—	—
Norway ... ..	160	6	—	96	72	—	1
Portugal ... ..	1,761	2,125	1,292	1,888	1,523	1,240	627
Spain ... ..	3,569	3,060	1,791	1,693	—	43	—
Sweden ... ..	1,479	812	—	—	—	—	—
Portuguese East Africa	11	1,925	682	1,694	370	215	22
United States ... ..	80	—	—	—	—	—	—
Bolivia ... ..	388	102	914	3,836	2,049	10,866	7,907
Chile ... ..	39,028	25,327	12,776	5,110	2,292	491	927
Peru ... ..	6,451	2,814	608	984	117	102	477
Venezuela ... ..	12,949	1,700	—	—	—	—	—
Japan (including Formosa and Japanese leased territories in China)	539	676	491	188	—	—	—
<b>Other Foreign Countries</b>	<b>1,590</b>	<b>419</b>	<b>897</b>	<b>1,585</b>	<b>976</b>	<b>251</b>	<b>441</b>
<b>Total from Foreign Countries</b>	<b>72,733</b>	<b>43,154</b>	<b>20,035</b>	<b>17,675</b>	<b>7,557</b>	<b>13,298</b>	<b>11,282</b>
<b>TOTAL ...</b>	<b>94,265</b>	<b>71,573</b>	<b>37,774</b>	<b>34,309</b>	<b>16,554</b>	<b>15,319</b>	<b>13,587</b>

*Imports of Copper Regulus, Matte and Precipitate into the  
United Kingdom*

(Annual Statements of the Trade of the United Kingdom)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Rhodesia ... ..	1,506	541	9	88	—	—	—
Union of South Africa	9,656	12,532	8,550	10,573	5,372	433	1,359
Australia ... ..	5,307	3,874	2,058	50	—	—	—
Canada ... ..	1,704	4,074	2,157	6,071	4,227	8,226	303
Other British Possessions	131	31	6	49	7	—	6
Total from British Possessions	18,304	21,052	12,780	16,831	9,606	8,659	1,668
Belgium ... ..	67	—	—	—	—	—	—
Germany ... ..	220	204	—	—	—	—	—
Portugal ... ..	2,214	2,057	3,756	1,859	924	2,095	1,773
Spain... ..	4,322	8,958	11,609	11,357	10,239	8,419	11,094
Portuguese East Africa	—	388	284	118	434	—	2,296
Mexico ... ..	9,637	7,634	8,371	12,969	3,559	—	—
United States ... ..	164	102	799	495	2,606	1,470	—
Bolivia ... ..	—	67	35	42	207	66	67
Chile ... ..	3,003	1,355	123	55	411	239	295
Peru ... ..	783	246	509	56	152	65	23
Other Foreign Countries	396	480	20	57	100	—	111
Total from Foreign Countries	20,806	21,491	25,506	27,008	18,632	12,354	15,659
TOTAL ... ..	39,110	42,543	38,286	43,839	28,238	21,013	17,327

*Imports of Copper, Rough and Refined, Unwrought, in Bars, Blocks, Slabs, Cakes, Ingots and Cathodes into the United Kingdom*

(Annual Statements of the Trade of the United Kingdom)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Rhodesia ... ..	353	1,804	3,703	1,763	1,302	3,008	—
Australia ... ..	21,880	16,483	31,015	19,855	10,853	21,579	17,040
Other British Possessions	56	167	304	267	7	129	1,497
<b>Total from British Possessions</b>	<b>22,289</b>	<b>18,454</b>	<b>35,022</b>	<b>21,885</b>	<b>12,162</b>	<b>24,716</b>	<b>18,537</b>
Belgium ... ..	1,787	1,377	—	—	—	—	—
France ... ..	1,825	1,131	48	5	3	—	125
Germany ... ..	1,314	687	—	—	—	—	—
Norway ... ..	307	168	—	26	209	21	64
Spain ... ..	5,950	8,920	12,928	13,286	16,851	10,891	4,232
Belgian Congo ...	157	3,766	4,205	13,178	11,577	4,874	3,143
Portuguese East Africa	16	178	4,720	5,780	2,907	14,878	5,929
Mexico ... ..	2,977	3,516	4,881	4,418	1,984	—	—
United States ...	52,183	94,838	84,244	30,140	76,523	130,826	66,673
Chile ... ..	6,900	8,913	11,119	11,446	1,916	3,965	8,168
Peru ... ..	436	20	—	—	—	—	—
China (exclusive of Hong Kong, Macão and leased territories)	60	6	—	—	—	—	—
Japan (including Formosa and Japanese leased territories in China)	8,445	5,712	17,713	7,963	16,652	13,107	1,760
Other Foreign Countries	32	28	24	4	6	39	688
<b>Total from Foreign Countries</b>	<b>82,389</b>	<b>129,260</b>	<b>139,882</b>	<b>86,246</b>	<b>128,678</b>	<b>178,601</b>	<b>90,782</b>
<b>TOTAL ...</b>	<b>104,678</b>	<b>147,714</b>	<b>174,904</b>	<b>108,131</b>	<b>140,840</b>	<b>203,317</b>	<b>109,319</b>

*Imports of Old Copper (fit only to be re-manufactured) into the United Kingdom*

(Annual Statements of the Trade of the United Kingdom)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Egypt* ... ..	—	—	305	148	36	3	35
Union of South Africa...	432	284	292	613	420	23	83
India ... ..	11	4	—	565	227	—	—
Australia ... ..	95	47	32	8	47	—	—
Canada ... ..	187	160	84	—	9	—	—
British West Indies ...	89	33	90	85	26	41	26
British Guiana ... ..	14	—	—	—	—	—	—
Other British Possessions	122	85	60	126	73	36	57
<b>Total from British Possessions</b>	<b>950</b>	<b>613</b>	<b>863</b>	<b>1,545</b>	<b>838</b>	<b>103</b>	<b>201</b>
Egypt ... ..	267	144	—	—	—	—	—
Belgium ... ..	167	—	—	—	—	—	558
Denmark (including Farøe Islands)	159	98	—	1	—	—	10
France ... ..	247	206	46	1	—	1	33
Germany... ..	238	193	—	—	—	1	—
Italy ... ..	104	77	16	—	—	—	—
Netherlands ... ..	61	—	—	—	—	—	—
Norway ... ..	197	166	—	2	2	—	16
Sweden ... ..	106	—	—	—	—	—	—
Turkey ... ..	31	—	—	—	—	—	—
United States ... ..	1,294	1,347	368	81	—	—	105
Brazil ... ..	75	63	269	364	71	6	—
Chile ... ..	119	53	152	127	75	—	2
Other Foreign Countries	385	480	417	116	69	11	96
<b>Total from Foreign Countries</b>	<b>3,450</b>	<b>2,827</b>	<b>1,268</b>	<b>692</b>	<b>217</b>	<b>19</b>	<b>820</b>
<b>TOTAL ... ..</b>	<b>4,400</b>	<b>3,440</b>	<b>2,131</b>	<b>2,237</b>	<b>1,055</b>	<b>122</b>	<b>1,021</b>



*Imports of Copper, Part Wrought, into the United Kingdom*  
(Annual Statements of the Trade of the United Kingdom)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Total from British Possessions	—	—	—	10	—	1	247
Belgium ... ..	8	23	—	—	—	—	—
France ... ..	390	351	—	1	2	—	530
Germany... ..	184	160	—	—	—	—	—
United States ... ..	1,683	2,153	5,391	3,195	1,820	529	4,906
Other Foreign Countries	5	75	91	75	116	96	—
Total from Foreign Countries	2,270	2,762	5,482	3,271	1,938	625	5,436
TOTAL ... ..	2,270	2,762	5,482	3,281	1,938	626	5,686

*Imports of Manufactures of Copper, Unenumerated, into the United Kingdom*

(Annual Statements of the Trade of the United Kingdom)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Total from British Possessions	—	11	71	179	65	22	90
Belgium ... ..	193	222	—	—	—	—	16
France ... ..	5,734	3,442	777	59	21	15	994
Germany ... ..	5,411	4,222	1	4	—	—	47
Netherlands ... ..	69	56	6	—	—	12	1
United States ... ..	1,464	2,298	5,445	1,339	1,461	1,654	1,605
Other Foreign Countries	36	16	98	1	12	5	2
Total from Foreign Countries	12,907	10,256	6,327	1,403	1,494	1,686	2,665
TOTAL... ..	12,907	10,267	6,398	1,582	1,559	1,708	2,755

*of Pyrites of Iron and Copper into the United Kingdom*  
*Annual Statements of the Trade of the United Kingdom)*

Quantity (long tons)						
	1914	1915	1916	1917	1918	1919
6	8,168 10	— —	— —	— —	— —	— —
6	8,178	—	—	—	—	—
0	2,056	9,700	7,422	—	—	3,597
0	7,557	—	11,923	600	—	8,064
5	106,672	78,281	24,639	49,960	112,889	14,929
3	73,219	59,143	83,506	31,096	28,003	15,915
0	604,367	751,978	819,465	772,585	695,811	299,662
7	1,100	3,365	3,041	—	—	2,290
5	794,971	903,467	949,996	854,241	836,703	344,457
1	803,149	903,467	949,996	854,241	836,703	344,457

*Exports of Copper Regulns, Matte, Precipitate and Residues  
from the United Kingdom (Domestic Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Total to British Possessions	—	2	—	—	—	—	1
Germany ... ..	10	1,009	—	—	—	—	—
United States ... ..	1,663	531	1,130	1,472	1,101	516	178
Other Foreign Countries ...	197	11	90	—	—	—	146
Total to Foreign Countries	1,870	1,551	1,220	1,472	1,101	516	324
TOTAL ... ..	1,870	1,553	1,220	1,472	1,101	516	325

*Exports of Copper, Uncwrought, in Ingots, Cakes or Slabs, from  
the United Kingdom (Domestic Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Union of South Africa ...	59	—	—	—	—	—	—
British East Indies ...	457	331	464	97	34	5	3,323
Other British Possessions	31	53	35	49	30	2	77
Total to British Possessions	547	384	499	146	64	7	3,400
Austria-Hungary ... ..	110	40	—	—	—	—	—
Belgium ... ..	682	471	—	—	—	—	1,370
Denmark (including Farøe Islands)	147	93	238	191	50	—	127
France ... ..	5,837	3,900	3,394	5,913	4,288	3,965	1,386
Germany ... ..	823	528	—	—	—	—	—
Italy ... ..	953	340	824	1,623	225	—	—
Netherlands ... ..	1,495	479	171	—	—	5	734
Russia ... ..	53	459	987	893	150	—	15
Spain ... ..	—	102	192	169	282	5	350
Sweden ... ..	272	159	36	77	30	11	214
United States ... ..	3,490	60	190	119	—	—	—
Japan ... ..	—	—	—	—	—	—	2,547
Other Foreign Countries ...	498	234	126	58	88	41	592
Total to Foreign Countries	14,360	6,865	6,158	9,043	5,113	4,027	7,335
TOTAL ... ..	14,907	7,249	6,657	9,189	5,177	4,034	10,735

*Exports of Wrought or Manufactured Copper mixed or yellow metal from the United Kingdom (Domestic Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Canada ... ..	16	10	—	17	—	—	2
Hong Kong ... ..	727	532	53	114	27	25	270
India ... ..	10,451	10,151	2,247	557	195	13	6,188
Straits Settlements ... ..	165	178	133	103	53	24	110
Australia ... ..	766	547	302	150	39	12	150
Other British Possessions	333	267	182	199	42	52	177
Total to British Possessions	12,458	11,685	2,917	1,140	356	126	6,897
France ... ..	71	71	162	53	20	—	15
Italy ... ..	137	115	69	4	—	—	—
Netherlands ... ..	227	130	101	15	2	2	78
Norway ... ..	76	57	26	1	1	—	39
Portugal ... ..	46	42	31	43	36	41	64
Spain ... ..	113	61	20	1	—	1	46
Argentina... ..	102	117	4	—	—	1	10
Brazil ... ..	325	135	73	62	7	6	47
Chile ... ..	97	92	49	37	17	12	32
China ... ..	33	50	24	16	1	—	86
Japan ... ..	42	37	—	2	—	—	—
Philippine Islands and Guam	176	168	117	106	6	3	29
Siam ... ..	79	38	47	36	—	—	14
Other Foreign Countries	490	404	169	98	18	31	158
Total to Foreign Countries	2,014	1,517	892	474	108	97	618
TOTAL ... ..	14,472	13,202	3,809	1,614	464	223	7,515

*Exports of other kinds of wrought or manufactured Copper from  
the United Kingdom (Domestic Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Egypt* ... ..	—	—	263	174	46	72	1,340
Union of South Africa	1,226	625	464	400	202	92	621
Canada ... ..	96	36	7	27	12	—	21
India ... ..	7,391	5,230	3,718	691	371	658	5,413
Australia ... ..	4,883	4,333	3,372	2,662	288	351	1,312
New Zealand ... ..	671	490	618	261	52	29	253
Other British Possessions	1,228	1,019	499	346	140	65	448
<b>Total to British Possessions</b>	<b>15,495</b>	<b>11,733</b>	<b>8,941</b>	<b>4,561</b>	<b>1,111</b>	<b>1,267</b>	<b>9,408</b>
Egypt ... ..	1,153	999	—	—	—	—	—
Belgium ... ..	69	39	—	—	—	—	848
France ... ..	261	497	935	1,840	1,531	969	332
Denmark (including Farøe Islands)	51	168	145	29	5	—	88
Germany ... ..	136	100	—	—	—	—	—
Greece ... ..	56	91	178	2	2	—	101
Italy ... ..	51	31	209	22	160	3	74
Netherlands ... ..	133	366	652	239	6	5	1,297
Norway ... ..	136	238	432	193	64	21	784
Portugal ... ..	98	101	100	139	29	71	142
Russia ... ..	47	60	223	164	360	—	45
Spain ... ..	190	161	241	295	33	13	515
Sweden ... ..	166	322	120	38	—	—	82
Turkey ... ..	756	870	14†	—	—	—	319†
United States ... ..	284	248	499	8	7	1	—
Argentina ... ..	593	346	193	156	30	86	354
Brazil ... ..	861	326	219	73	3	3	141
Chile ... ..	162	101	40	38	19	19	83
China (exclusive of Hong Kong, Macão, and leased territories)	71	103	134	33	14	2	109
Japan (including Formosa and Japanese leased territories in China)	315	250	49	2	—	—	12
Persia ... ..	86	181	26	4	5	1	24
Java ... ..	298	204	171	21	3	—	94
Other Foreign Countries	491	559	339	157	35	24	471
<b>Total to Foreign Countries</b>	<b>6,464</b>	<b>6,355</b>	<b>4,919</b>	<b>3,453</b>	<b>2,306</b>	<b>1,218</b>	<b>5,915</b>
<b>TOTAL ... ..</b>	<b>21,959</b>	<b>18,088</b>	<b>13,860</b>	<b>8,014</b>	<b>3,417</b>	<b>2,485</b>	<b>15,323</b>

\* Egypt is shown under Foreign Countries prior to 1915.

† Exported to ports or places in territory formerly Turkish but now occupied by other Powers.

*Exports of Sulphate of Copper from the United Kingdom  
(Domestic Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Egypt* ... ..	—	—	36	350	39	81	12
British South Africa	—	29	57	146	94	59	21
India ... ..	—	—	72	235	46	6	88
Canada ... ..	530	121	170	344	19	—	41
Australia ... ..	992	1,035	642	434	386	62	38
Other British Possessions	529	456	176	209	110	35	62
<b>Total to British Possessions</b>	<b>2,051</b>	<b>1,641</b>	<b>1,153</b>	<b>1,718</b>	<b>694</b>	<b>243</b>	<b>262</b>
Austria-Hungary ...	2,540	2,125	—	—	—	—	—
Belgium ... ..	434	175	—	—	—	—	49
France ... ..	21,767	23,704	34,494	21,776	39,402	41,073	16,506
Germany ... ..	953	459	—	—	—	—	—
Greece ... ..	2,627	3,060	1,615	8	—	589	2,282
Italy ... ..	27,128	17,046	9,588	3,980	66	—	2,830
Netherlands ...	943	1,005	367	21	1	—	181
Portugal ... ..	4,449	3,152	3,498	1,452	1,469	1,566	1,275
Roumania...	2,368	2,680	1,488	1	—	—	3,664
Russia ... ..	2,977	4,156	1,614	6,930	1,651	—	4,458
Spain ... ..	4,965	5,274	5,895	45	3	—	46
Switzerland ...	—	—	1,527	247	106	497	907
Algeria ... ..	411	287	1,627	2,658	3,643	3,516	916
Other Foreign Countries	2,020	3,134	2,345	83	95	112	1,693
<b>Total to Foreign Countries</b>	<b>73,582</b>	<b>66,257</b>	<b>64,058</b>	<b>37,201</b>	<b>46,436</b>	<b>47,353</b>	<b>34,807</b>
<b>TOTAL ... ..</b>	<b>75,633</b>	<b>67,898</b>	<b>65,211</b>	<b>38,919</b>	<b>47,130</b>	<b>47,596</b>	<b>35,069</b>

\* Egypt is shown under Foreign Countries prior to 1915.

*Exports of Copper, Unwrought, in Bars, Blocks, Slabs, Cakes and Ingots from the United Kingdom (Colonial and Foreign Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
India ... ..	253	30	201	—	—	—	376
Other British Possessions	2	3	—	—	—	1	—
Total to British Possessions	255	33	201	—	—	1	376
Belgium ... ..	—	—	—	—	97	—	1,488
France ... ..	101	150	701	57	124	—	1,946
Germany ... ..	1,960	381	—	—	—	—	500
Italy ... ..	1,128	225	1,880	3,643	2,776	646	—
Netherlands ... ..	1,433	405	247	30	—	—	431
Russia ... ..	20	3,698	1,062	385	70	—	—
Sweden ... ..	51	206	1,407	1,853	—	23	5
United States ... ..	13,987	5,380	1,680	1,132	—	—	451
Japan (including Formosa and Japanese leased territories in China)	—	—	—	—	—	—	2,200
Other Foreign Countries...	343	45	122	230	60	2	210
Total to Foreign Countries	19,023	10,490	7,099	7,330	3,127	671	7,231
TOTAL ... ..	19,278	10,523	7,300	7,330	3,127	672	7,607

*Exports of Copper, Part Wrought, from the United Kingdom (Colonial and Foreign Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Total to British Possessions	1	52	—	5	—	—	311
Total to Foreign Countries	23	111	40	—	—	—	—
TOTAL ... ..	24	163	40	5	—	—	311

*Exports of Manufactures of Copper, Unenumerated, from the United Kingdom (Colonial and Foreign Produce)*

(Annual Statements of the Trade of the United Kingdom)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Total to British Possessions	70	49	33	3	1	1	135
France ... ..	25	56	—	3	2	1	12
Netherlands ... ..	45	1	290	2	—	—	222
Russia ... ..	8	1	74	—	—	—	—
Other Foreign Countries ...	81	54	7	57	1	—	2
Total to Foreign Countries	159	112	371	62	3	1	236
TOTAL ... ..	229	161	404	65	4	2	371

**Rhodesia.\***

Most of the copper mines of Southern Rhodesia owe their development to the fact that their ores contain gold.

The principal producer in recent years has been the Falcon mine, at Umvuma, which has yielded considerable amounts of gold in addition to copper, the recovery in recent years averaging about 2 per cent. of copper and  $4\frac{1}{2}$  dwt. of gold per ton of ore. The Falcon lode is similar in character to that of the Valley Mine at Gwanda, but is richer in copper and of greater width, the width increasing from 17 feet at the 3rd level to 50 feet on the 9th level. The main shaft has reached a depth of over 1,100 feet and at 31st March, 1919, the ore reserves were estimated at about 700,000 tons. The treatment plant, installed in 1915, consists of 36 Nissen stamps, with tube mills, vanners, etc., and a flotation-plant, and has a capacity of 500 tons of ore per day.

Development work on a number of other properties is said to have proved the existence of large tonnages of ore.† These properties include the Umkondo mine, in south-east Mashonaland; the Skipper mine at Sinanombi; and the Alaska mine at Lomagundi.

The industry suffered during 1918-1919 from the ravages of the influenza epidemic, which seriously affected the supply of native labour, while the output of the Falcon mine was reduced by shortage of coal. The pooling of supplies of stores and

\* Annual Reports of the Secretary for Mines, Southern Rhodesia. Annual Reports of the British South Africa Company.

† The S. African Journ. Industries, Oct. 1918. The Mineral Resources of Rhodesia, by F. P. Mennell.



machinery, and the development of local resources assisted the mining industry in meeting some of the difficulties with which it was faced during the war.

In order to encourage the base-metal industry and especially to help the small worker to market his output, the British South Africa Company\* arranged in 1915-1916 that ores or metals delivered to the Company in Rhodesia should be sold by it on behalf of the producer, on the best terms possible, advances of cash being made in approved cases up to 50 per cent. of the estimated net proceeds. In addition, special rates were granted by the railway companies.

The most important copper property in Northern Rhodesia is the Bwana M'kuḥwa mine, which is connected by railway with the port of Beira, 1,450 miles distant. The ore-body has been traced for a length of 1,800 feet along its strike, and is roughly 100 feet in width.† During 1913-14, 22,807 tons of ore were stoped, the copper output being declared at 904 tons having an estimated local value of £32,739.‡ In 1918, the ore reserves down to the sixth level were estimated at 23,000 tons containing 10 per cent. of copper, 3,000,000 tons containing 4·5 per cent. and 1,200,000 tons of lower-grade material. For the year ended 30th June, 1918, the production was reported as 16,295 tons of ore yielding 1,419 tons of concentrates averaging 40 per cent. of copper. The output of the mine has been considerably restricted owing to the shortage of shipping.

A concentrating plant has been erected at the mine capable of treating 100 tons of ore per day by the flotation method.

The Kansanchi mine was re-started in August, 1913, and produced during eight months working 271 tons, valued at £15,234.

In 1913-1914 about 2,200 tons of coppermatte, which had been lying for some years at the Sable Antelope mine, in the Kafue district, was shipped to England.

### *Production of Copper (including Concentrates and Finished Copper) in Northern Rhodesia*

(Annual Reports of the Rhodesia Chamber of Mines, and information furnished by the British South Africa Company)

Year						Quantity (long tons)
1913§	...	...	...	...	...	5,856
1914	...	...	...	...	...	763
1915	...	...	...	...	...	176
1916	...	...	...	...	...	1,159
1917	...	...	...	...	...	1,803
1918	...	...	...	...	...	793
1919	...	...	...	...	...	182

\* Report of the British S. Africa Co. for the year ended 31st March, 1916.

† Report of the British S. Africa Co. for the year ended 31st March, 1914

p. 36. ‡ Report of the Secretary of Mines, N. Rhodesia, 31st March, 1914.

§ From 1906 to Dec. 31st, 1913.

*Production of Copper in Southern Rhodesia*

(Annual Reports of the Secretary for Mines, Southern Rhodesia)

Year						Quantity (long tons)
1913	...	...	...	...	...	—
1914	...	...	...	...	...	903
1915	...	...	...	...	...	3,140
1916	...	...	...	...	...	3,144
1917	...	...	...	...	...	3,493
1918	...	...	...	...	...	2,905
1919	...	...	...	...	...	2,689

**Union of South Africa.\*****TRANSVAAL.**

The principal deposit of copper ore developed in the Transvaal is that of the Messina mine in the Zoutpansberg district. This deposit occupies a fissure in the gneisses forming the basement rock of the country, is from 200 to 300 feet in width, and can be traced for some 20 miles.

The bulk of the ore consists of bornite, with some chalcocite near the surface. It is found in massive lenses in the upper levels, while in the lower levels it is finely disseminated in the gangue, its somewhat irregular occurrence involving a large amount of unproductive work. The mine is developed to a depth of about 1,800 feet, where the ore-bodies, though poorer than at the surface, continue downwards.

The Messina (Transvaal) Development Company started production in 1906, and by 1915-16 the production of copper had risen to 5,732 tons, obtained from 112,043 tons of ore, averaging 5.43 per cent. of copper. In 1918-19 the production was 2,703 tons of copper.

On June 30, 1919, the reserves were estimated at 415,500 tons of 3.25 per cent. ore, with 325,000 tons of 1.4 per cent. jig-tailings. The mill has a capacity of 250 tons per day, and two reverberatory furnaces have been erected. The concentrates, which contain about 40 per cent. of copper, are exported, but the middlings are smelted on the spot to a 50 per cent. matte before shipment. A new smelting and refining plant is being erected. Costs increased considerably during the war, but were off-set by higher prices for copper and by better metallurgical recoveries.

Development on the farm Vogelsang, on what appears to be the extension of the vein worked at Messina, has given encouraging results. In 1919, the Messina and Vogelsang shafts had reached depths of 1,033 feet and 1,742 feet respectively, and were connected by extensive underground workings.

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\* Annual Reports of the Government Mining Engineer for the Union of South Africa.

Between Messina and the Macoutsie River, in the vicinity of Motali and M'tamba, other copper deposits have been opened up to some extent.

At the Willows mine, near Hatherley, which was worked for some time, the ore consists of chalcopyrite and copper carbonates, with iron-pyrites, tetrahedrite and a large amount of siderite.

Copper is associated with zinc, lead and manganese ores in the auriferous quartz veins of Malmari, in dolomite; and in association with silver and lead in the Transvaal silver mine.

In the Bushveld igneous rocks many lodes of copper and silver ore are met with. At the Albert mine, 29 miles north-east of Bronkhorst Spruit on the Middleburg railway, a dolerite intrusion, impregnated locally with copper and silver, penetrates a fissure in porphyritic red granite which carries copper ore in lenses. The vein-filling consists mainly of hæmatite associated with bornite, chalcopyrite, tetrahedrite and silver.

At the Marks Drift mine, on the Orange River, a lode containing copper ore has been worked in dolerite, which is intrusive into the Black Reef Series.

In the Murchison Range there are numerous occurrences of copper ore, and many prehistoric workings have been found.

Near D'Sjate, in the valley of the Mopetsi River, in the Lydenburg district, copper ore was quarried and smelted in ancient times.

There was intensive production in the Union of South Africa in 1914-15, with increased shipments of copper concentrates, matte and copper. There has since been a persistent decline in production, but the increased price of the metal has to some extent compensated for the reduced output.

### *Production of Copper in the Transvaal*

(Annual Reports of the Government Mining Engineer)

Year		Crude Ore treated*	Marketable Product†		Sales and Shipments‡	
		Quantity (long tons)	Quantity (long tons)	Average percentage of pure Metal	Quantity (long tons)	Average percentage of pure metal
1913	...	30,663	5,137	44·14	4,721	43·76
1914	...	74,461	13,631	40·39	13,354	39·84
1915	...	102,979	12,952	42·79	13,390	43·38
1916	...	134,405	10,782	47·34	10,931	47·40
1917	...	142,606‡	8,126	52·34	8,577	51·44
1918	...	110,579	5,870	55·12	4,648	53·28
1919	...	86,634	4,039	63·08	4,115	60·70

\* Including ore concentrated and ore smelted.

† Including concentrates, matte, middlings and blister.

‡ Including 214 tons of Cape ore.

## CAPE PROVINCE.

Copper mining has been carried on in this province since 1852, the total recorded value of the copper output to 31st December, 1916, being £18,820,353.\*

During the period 1913-15, the Cape and Namaqua Copper Companies produced picked ore assaying from 22 to 24 per cent. of copper, matte assaying 46 to 51·5 per cent., and precipitate assaying from 69 to 70·6 per cent.

In the years 1913 to 1916 the Cape output of copper-matte averaged about 12,000 tons per annum, but a considerable decline in production followed, the copper sales and shipments in 1919 being valued at only £17,656. It is understood, however, that the Cape Copper Company had copper ore and metal in stock at the end of that year amounting in value to more than £275,000.

Occurrences of copper ore have been noted in the Cradock and Cathcart districts, also at the Insizwa mine in the Mount Ayliff district, where the copper is associated with nickel and platinum.

The Insizwa mine was worked intermittently during 1911, and again in 1914, but is not now producing. Samples of the ore are stated to have assayed: copper 1 to 19 per cent. (averaging 4·1), nickel 0·6 to 7·3 per cent. (averaging 3·8), and platinum from 12 grains to nearly 5 oz. per ton. Traces of cobalt, silver, gold and osmiridium were also present.

The most important copper mines in Little Namaqualand are those of the Cape Copper Company, Limited, and the Namaqua Copper Company, Limited. The former company is working the O'okiep, Nababeep South, Nababeep North and Narrap mines, the ores of which consist mainly of bornite and chalcopryite, with some chalcocite, and carbonates, &c., at the surface. The country rock is gneiss, and the pay-ore is found in dykes and irregular masses of various igneous rocks, consisting of mica-diorite at O'okiep, hypersthenite at Nababeep, and norite at the Tweefontein mine of the Namaqua Copper Company. The O'okiep and Nababeep ore-bodies appear to cut out at a depth of about 600 feet, and the Tweefontein ore-body at about 980 feet. The Narrap mine, which lies about one mile east of O'okiep East and on the same eruptive dyke as Nababeep, yielded in 1916 about 4,000 tons of 5·37 per cent. copper ore. The Nababeep South deposit occurs in a mass of basic igneous rock, forming a hill, five to six miles west of O'okiep, and is now the principal producer. In April, 1916, the reserves were estimated at 120,000 tons, assaying 5·0 per cent. of copper.

The O'okiep main deposit, which is about 1,000 feet in length and 200 feet in width, was formerly the chief producer, but its ore reserves were estimated in 1916 at only 6,000 tons of 20 per cent. copper ore. The output of ore for the year ending April 30th, 1916, amounted to about 13,000 tons, averaging 11·22 per cent. of copper, while 120,000 tons of 4 per cent. ore were estimated to be dumped at the surface.

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\* The Base Metal Resources of the Union of South Africa, by W. Versfeld, Dept. of Mines and Industries, 1919.

Other properties owned by the Company in the neighbourhood of O'okiep include the Specktakel, Carolusberg Flat, and Kopperberg mines, which are at present idle.

There is a central electric-power station at O'okiep. The smelter at NababEEP was enlarged in 1913 after closing down the smelter at O'okiep. During the year ended April 30th, 1916, about 80,000 tons of ore were treated at NababEEP, a 48 to 50 per cent. matte being produced and shipped to England. The poorer ores are concentrated, but those carrying more than 4 per cent. of copper are smelted direct. Some of the ores are leached, the copper being precipitated on scrap iron. In 1916 the precipitate produced by the Cape Namaqualand companies contained about 75 per cent. of copper. A railway, 99 miles in length, connects O'okiep with Port Nolloth, which is suitably equipped for the shipment of ore and matte to the Cape Company's treatment works at Briton Ferry, in South Wales, where the richer ores are refined by the "Nichols direct method," without calcining, and the matte is re-treated and converted into fine copper.

The Namaqua Copper Company, Limited, owns the Tweefontein, Wheal Julia and Henderson mines at Concordia, Little Namaqualand. In December, 1918, the ore reserves were estimated at 37,655 tons, averaging 5·8 per cent of copper, with about 24,000 tons of accumulated slimes and tailings. The properties are equipped with mining, milling, flotation, briquetting, precipitation, and smelting plants. In 1916, 1,800 tons of fine copper were produced, but, owing to the suspension of copper shipments from South Africa, smelting ceased in May, 1918, in which year 7,356 tons of ore were treated for a yield of 450 tons of copper. The average cost of production at the Namaqualand mines was estimated at about £60 per ton of fine copper for 1916 and at over £80 per ton for the first six months of 1917, the cost of delivering the matte in England, including insurance, being about £35 per ton.

In 1918 the Cape Copper and Namaqua Copper Companies experienced difficulties owing to shortage of coke and other supplies, absence of shipping facilities, and a fall in the price of copper which adversely affected the realization of stocks. The coke difficulty was the most serious, as the Natal product did not prove to be a satisfactory substitute for English coke. The Namaqua Company met the difficulty by mixing English with Natal coke in the proportion of 1 to 3, and was able to dispose of its stock of metal to Japan at a satisfactory price.

*Production of Copper in Cape Province*

(Annual Reports of the Government Mining Engineer)

Year	Crude Ore treated	Marketable Product*		Sales and Shipments*	
	Quantity (long tons)	Quantity (long tons)	Average percentage of pure Metal	Quantity (long tons)	Average percentage of pure Metal
1913	96,911	12,509	47·32	11,692	48·06
1914	112,604	12,187	47·66	12,829	47·76
1915	117,856	11,829	44·61	12,476	44·48
1916	114,022	11,358	46·47	9,463	44·52
1917	67 868	8,105	45·9	9,398	47·66
1918	18,571	3,849	39·3	1,490	48·51
1919	17,645	1,937	50·18	247	74·62

\* Including picked ore, matte, bottoms and precipitate.

ORANGE RIVER COLONY

Copper ore has been found in the Heilbron and Bethulie districts.

NATAL

Copper has been found in a variety of rocks in the Vryheid district and Zululand, in the former locality in sheared granite zones and in the latter mostly in schists intersected by intrusive rocks. The Subeni and Dania mines in the Vryheid district are still at the prospecting stage.

SOUTH-WEST AFRICA TERRITORY\*

In this Territory the chief deposits of copper ore are those of the Otavi district, the most important mine being that of Tsumeb. Other large deposits have been developed at Gross Otavi, Asis, Asis East, Guchab and Bobos, in the Grootfontein district. The ore occurs as lenses in dolomite, the copper being generally associated with lead.

The Tsumeb mine, which is about 12 miles from Lake Otjikoto, contains the largest deposits. These occur in the grey dolomite of the Otavi Series as steeply dipping lenticular lenses, some of which are more than 75 feet in width. An intrusion of aplite lies on the foot-wall side of the two principal ore-bodies and separates them. The ore-bodies and the aplite are intersected by narrow igneous dykes. The ore, which is generally separated from the dolomite by a clay selvage, is a massive coarsely-crystalline aggregate, in which the valuable minerals are chiefly chalcocite, galena, zinc-blende and some sulphide-ores of copper containing arsenic and antimony, while an unusual number of oxidation products is

\* Copper Ores of Otavi, P. Krusch, Trans. Inst. Min. Eng., Vol. XLII., p. 617. Geology and Mineral Industry of South-West Africa, P. A. Wagner, Geol. Surv. Memoir No. 7, 1916.

found at the surface. The oxidized ores contained about 13 per cent. of copper and  $4\frac{1}{2}$  per cent. of lead. In the eastern lens the predominant mineral is galena, the average composition of the ore, as reported in 1919, being 50 per cent. lead, 10 per cent. copper, 0.02 per cent. silver, 1 to 2 per cent. arsenic, and 0.5 to 2 per cent. antimony. The bulk of the ore has probably averaged from 6 to 14 per cent. of copper. The western lens contains more copper, the ore averaging from 15 to 25 per cent. of that metal, 20 to 30 of lead, 0.5 of antimony, 1 to 2 of arsenic and 0.02 to 0.03 per cent. of silver. The greater part of the ore in this lens has probably averaged 12 to 15 per cent. copper. The Tsumeb ores appear to have contained from 18 to 30 per cent. of lead.

The output of copper and lead ores from the Otavi mines for the year ended March 31st, 1913, was 54,100 tons. Of this total, 44,500 tons, containing 13 per cent. copper, 25 per cent. lead, and over 7 oz. silver per ton, was shipped. During the same period the Otavi Company shipped 655 tons of matte, containing 48 per cent. of copper, 25 per cent. of lead, and over 14 oz. of silver per ton, also 400 tons of pig-lead, containing 98 per cent. of lead and over 29 oz. of silver per ton.

In 1913-14 the Grootfontein district produced 50,070 tons of copper and lead ores and 1,179 tons of copper matte.

In 1918 the Otavi Company exported 7,358 tons of ore, assaying from 12 to 33 per cent. of copper and 12 to 22 per cent. of lead, and at the end of that year the company had in stock 139,322 tons of ore, assaying from 2 to 41 per cent. of copper. Low-grade ores were formerly smelted locally, but most of the Otavi ores were shipped to America, the German smelters having imposed a penalty on ore containing more than 6 per cent. of zinc, for which metal no payment was made.

During 1919 and 1920, copper ore was won and exported as follows\* :—

Company.	1919.				1920.			
	Ore won.		Ore exported.		Ore won.		Ore exported.	
	Tons.	Value (£).	Tons	Value (£).	Tons.	Value (£).	Tons.	Value (£).
Otavi Mines and Railway Company.	26,570	115,780	6,400	115,200	36,291	217,744	30,511	183,066
Otavi Exploring Syndicate, Ltd.	105	4,220	206	9,888	16	652	80	3,204
TOTAL ...	26,675	120,000	6,606	125,088	36,307	218,396	30,591	186,270

At 1st January, 1921, 9,058 tons of copper ore were at Walvis Bay, awaiting export.

\* Report of the Administrator, South-West Africa Territory, Union of South Africa, for year 1920 : Cape Town 1921.

Numerous other deposits of copper ore occur in various parts of the Territory. Next to Tsumeb, the Khan mine is said to contain the most important occurrence of copper in South-West Africa. It is situated about seven miles S.S.E. of Arandis, in the Swakopmund district. The deposit consists of a vein of coarse-grained copper-bearing pegmatite in gneiss mineralized over a length of from 1,100 to 1,300 feet. It has been developed to a depth of 690 feet on the incline, the width varying from 8 inches to 7 feet, and in its northern part carries about  $7\frac{1}{2}$  per cent. of copper, chiefly in the form of bornite; some copper-glance, chalcopyrite and malachite being also present. Zinc-blende occurs in some parts of the ore-body. A considerable tonnage of ore has been blocked out, and a crushing and concentration plant of modern type, erected in 1913-14, was in operation before the outbreak of the war, a concentrate containing from 60 to 70 per cent. of copper being made and shipped to Europe. The plant has a capacity of 50 tons per day. The Henderson and Ehler mines, situated south-west of Usakos, are of the same type.

The Otjizongati mine, north-west of the Onyati Mountains and north-east of Windhuk, has been worked for some years. The ore occurs in lenticular veins of pegmatitic quartz up to 6 feet in width traversing mica-schist and gneiss. The primary ore is chalcopyrite and pyrite, associated with rutile, molybdenite, tourmaline and apatite. Near the surface the veins carry cuprite, native copper and malachite, and in the cementation zone chalcocite, bornite, and black oxide of copper. Veins of similar type and character occur at Rehoboth, at Spitzkopjes, and at Gaidip, near Ramans Drift, on the Orange River, containing free gold as well as copper, but the quantity of ore available, although fairly rich, is small. The Sinclair mine, in the Lüderitz Bay district, has been worked intermittently for 60 years. The deposit occurs in porphyry as a vein of white quartz, from 12 to 15 feet in width, which splits into several branches, one of which (3 to 4 feet in width) contains chalcocite in thin bands and irregular patches, accompanied near the surface by carbonates and black oxide of copper.

At the Gorap mine, south-east of Walvis Bay, an impregnation deposit has been worked, consisting of a series of lenticular masses of quartzite in mica-schist. The deposit outcrops over a distance of about 3 miles, and has an average width of about 6 feet. At the surface the ore is an intimate mixture of cuprite, malachite, chrysocolla and limonite.

At the Matchless mine, about 19 miles south-east of Windhuk, the primary ore is cupreous iron-pyrites, associated with arsenical pyrites.



*Production of Copper in the Union of South Africa*  
(Annual Reports of the Government Mining Engineer)

Year	Crude ore treated*	Marketable Product†	Sales and Shipments†	
			Quantity (long tons)	Average percentage of pure metal
1913 ... ..	127,574	17,646	16,413	46·82
1914 ... ..	187,065	25,818	26,183	43·72
1915 ... ..	220,835	24,781	25,866	43·91
1916 ... ..	248,427	22,140	20,394	46·06
1917 ... ..	210,474	16,231	17,975	49·46
1918 ... ..	129,150	9,719	6,138	52·12
1919 ... ..	104,279	5,976	4,362	61·48

\* Including crude ore concentrated and crude ore smelted.

† Including concentrates, picked ore, matte, bottoms, middlings and precipitate.

*Imports of Copper Plate and Sheet\* into the Union of South Africa*

(Annual Statements of the Trade and Shipping of the Union of South Africa and of Southern and Northern Rhodesia)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
United Kingdom ... ..	41	34	36	24	10	1	19
United States ... ..	—	—	1	1	3	25	47
Other Countries ... ..	7	5	1	—	2 cwt.	2	9 cwt.
TOTAL ... ..	48	39	38	25	13	28	66

\* Excluding Government Stores.

*Imports of Copper Bar, Ingot and Rod\* into the Union of South Africa.*

(Annual Statements of the Trade and Shipping of the Union of South Africa and of Southern and Northern Rhodesia)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
United Kingdom ... ..	68	45	36	44	15	—	7
United States ... ..	3	—	7	10	8	38	21
Other Countries ... ..	3	1 cwt.	—	1 cwt.	1 cwt.	22	1
TOTAL ... ..	74	45	43	54	23	60	29

\* Excluding Government Stores.

*Imports of Copper\* into the Union of South Africa  
(Government Stores)*

(Annual Statement of the Trade and Shipping of the Union of  
South Africa and of Southern and Northern Rhodesia)

Year	Quantity (long tons)		
	Bar, ingot, and rod	Plate and sheet	Pipes and piping
1913 ... ..	53	172	38
1914 ... ..	15	140	4
1915 ... ..	20	121	3
1916 ... ..	58	45	23
1917 ... ..	71	21	8
1918 ... ..	97	50	2
1919 ... ..	125	258	—

\* Imported almost entirely from the United Kingdom. In addition to these imports, the Union imported 150 tons of copper wire per annum during the years 1916-1919.

*Exports of Copper Ore and Concentrates from the Union of South  
Africa (Domestic Produce)*

(Annual Statement of the Trade and Shipping of the Union of  
South Africa and of Southern and Northern Rhodesia)

Year	Quantity (long tons)					
1913 ... ..	...	...	...	...	...	7,040
1914 ... ..	...	...	...	...	...	17,491
1915 ... ..	...	...	...	...	...	14,342
1916 ... ..	...	...	...	...	...	13,658
1917 ... ..	...	...	...	...	...	8,678
1918 ... ..	...	...	...	...	...	4,665
1919 ... ..	...	...	...	...	...	5,803

With the exception of 10 tons to Australia and 1,566 tons to Japan in 1918, all exported to the United Kingdom.

*Exports of Copper (Regulus, Matte and Smelted) from the Union  
of South Africa (Domestic Produce)*

(Annual Statements of the Trade and Shipping of the Union of  
South Africa and of Southern and Northern Rhodesia)

Year	Quantity (long tons)					
1913 ... ..	...	...	...	...	...	9,500
1914 ... ..	...	...	...	...	...	10,924
1915 ... ..	...	...	...	...	...	11,477
1916 ... ..	...	...	...	...	...	7,585
1917 ... ..	...	...	...	...	...	7,648
1918 ... ..	...	...	...	...	...	1,509
1919 ... ..	...	...	...	...	...	45

With the exception of 1,408 tons to Japan in 1918, all exported to the United Kingdom.

### Canada.\*

Canada possesses very important and well-developed copper deposits and a great number of smaller mines and "prospects" widely scattered over the Dominion from the Yukon Territory to Nova Scotia. Refined copper was first produced in Canada in 1916, when the output amounted to 431 tons, while in 1918 3,401 tons were produced, and in 1919, 3,113 tons. British Columbia contributed 52.9 per cent. of the total production of Canada in 1918, Ontario 39.6 per cent., Quebec 5.0 per cent., Manitoba 2 per cent., and the Yukon 0.5 per cent.

Canada is remarkable, among copper-producing countries, for its immense deposits of copper-nickel ore in Ontario. It is noteworthy that these occurrences were at first regarded as of value only for the copper they contained. Canadian copper-ore deposits are of the most varied description, some carrying copper alone, others containing gold, some gold and silver, and others various base metals, particularly silver-lead and zinc.

The consumption of copper in Canada has hitherto been about 20,000 tons per annum, or less than half the production of British Columbia alone, where the production is controlled to the extent of 90 per cent. by American capital.

About half the production in the past has been exported as Bessemer copper containing 95 to 99 per cent. copper and some gold and silver, but much of this is now likely to be treated at Trail, where a refinery was erected in 1916, the power being furnished by a hydro-electric installation. The original capacity of this refinery was increased from 10 tons to 45 tons per day in 1918.

### NOVA SCOTIA

The principal copper deposits opened up in this province are the Cheticamp mines in Inverness County, which are stated to be situated on a mineralized zone in micaceous schist, 350 feet wide, traceable  $1\frac{1}{2}$  miles, carrying several ore-bodies, three of which have been developed to a depth of 200 feet. The Company claims to have developed 250,000 tons of sulphide ore averaging from 2.5 to 3.5 per cent. copper and 18 per cent. lead, with 34 oz. of silver and from about 2 dwt. to nearly  $1\frac{1}{2}$  oz. of gold per ton.

The old Coxheath mine, Cape Breton County, ten miles from Sydney, contains several cupriferous veins. The principal veins, said to average 10 feet in width, traverse felsite and diorite and carry auriferous chalcopyrite in a siliceous gangue, averaging about 4.5 per cent. copper. They were developed to 420 feet in depth, but have been idle for many years.

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\* Annual Reports on the Mineral Production of Canada. Annual Reports of the Bureau of Mines, Ontario. Annual Reports of the Minister of Mines, British Columbia. Canada Year Book. Summ. Repts. Geol. Surv. Canada.

At Polson's lake, Antigonish County, a vein, said to be 5 feet wide and traceable for about a mile, is stated to carry argentiferous and auriferous copper ore and to have been developed to a depth of about 100 feet.

There are copper properties at Wentworth, Cumberland County, which are apparently idle at present.

#### NEW BRUNSWICK

No large copper deposits have as yet been found in this province, but this may perhaps be partly attributed to the fact that the area is very heavily forested, rendering prospecting difficult. At Dorchester, Westmoreland County, a vein has been developed and is said to contain from 3 to 4 per cent. of copper as sulphides and carbonates.

#### QUEBEC

The copper production of Quebec is derived from cupreous pyrites occurring mainly in Sherbrooke and Wolff Counties.

In the former County at the Albert mine, Capelton, there are lenticular deposits of chalcopyrite and pyrite assaying up to 5 per cent. copper, and 38 per cent. sulphur. This mine has six shafts, one 2,000 feet deep, connected with 5 miles of workings.

The works include a 150-ton concentrator, a smelter and acid plant. The acid plant has a daily capacity of 150 tons of sulphuric acid, and is equipped for the manufacture of sulphuric, nitric and hydrochloric acid, and Glauber salt. The cinder remaining from the burning of cupreous pyrites is smelted in a small blast-furnace, producing 1 to 2 tons daily of matte, assaying up to 40 per cent. copper with a little silver, which is shipped to Laurel Hill, New York, for refining. The copper production is estimated at 156 tons per annum.

On the property of the Eustis Mining Company, in the township of Ascot, there are four parallel interbedded lenses of cupreous pyrites, in talcose schists that are traversed by diorite dykes, the cupriferous belt being traceable for some two miles. The ore-body has been worked to a depth of about 4,100 feet on the incline, with a dip of about 38°. The lenses are from 3 to 60 feet in width, and from 50 to 350 feet in length, averaging about 2½ per cent. copper and containing up to 2s. 6d. per ton in gold and silver, with 40 per cent. sulphur. Selected ore and concentrates are shipped to acid works and roasted for sulphur, the cupriferous cinder being shipped to the Norfolk smelter. In the six years ending May 31, 1914, the mine produced 153,849 tons of shipping ore.

In Wolff County, the Weedon Mining Company mines two lenses in schist for sulphur and copper. The main ore-body is said to be 570 feet long and 15 to 45 feet wide. It has been developed by two shafts 700 and 965 feet deep, and the average ore is said to contain 3·3 per cent. copper, 40·8 per cent. sulphur, a trace of lead, 0·77 per cent. zinc, 0·5 oz. silver and about 5 grains of gold per ton. The ore reserves at the end of 1916 were estimated at 200,000 tons, the production of copper in that year being 2,546 tons.

## ONTARIO

The nickel-copper ores of the Sudbury area are the source of nearly all the copper produced in Ontario. These ores contain from 1 to 2.5 per cent. of copper, the recovery averaging a little over 1.5 per cent.

Copper ores free from nickel are found in many parts of the province, notably on the north shore of Lake Huron, at Bruce mines. This deposit yielded in all about £729,000 worth of copper. After remaining idle for many years, it passed into possession of the Mond Nickel Co., to whom the ore is of value as a flux on account of its siliceous character.

The mines of the Sudbury district, being chiefly important for their production of nickel, will be more fully described in the Bureau's publication on nickel, but it may be stated that the British-American Nickel Corporation is reported to have developed 18 million tons of cupriferous nickel-ore, of which 14 million tons were in the Murray mine, about four miles north-west of the town of Sudbury.

The International Nickel Company, Ltd., owns the Creighton mine (formerly held by the Canadian Copper Company) which has been developed to 1,000 feet in depth and produced about 3,100 tons of ore per day in 1919. The Crean Hill mine, developed to 780 feet, produced about 400 tons of sorted ore per day. The No. 2 mine at Copper Cliff, developed to a depth of 860 feet, produced about 200 tons of sorted ore per day. The nickel-copper properties owned by this Company are reported to contain a reserve of 20 million tons.

The Mond Nickel Company owns the Garson, Levack, Worthington, Victoria and other mines in the Sudbury district. The Victoria mine is the deepest mine in Ontario, being over 2,600 feet in depth. Unofficial estimates of the annual output of this Company's mines, made in 1916, placed it at about 1,780 tons of fine copper and 2,200 tons of nickel. The Mond Nickel Company erected a 1,500 ton smelter in 1912-13 at Coniston where a copper-nickel matte is made. This is exported to their refinery at Clydach, Swansea, where the metals are separated by the Mond Process.

Three processes are employed for the refining of nickel-copper mattes, viz., the Orford, the Mond and the Hybinette.

The International Nickel Company has erected a refinery\* at Port Colbourne, near the Lake Erie entrance of the Welland Canal, with a capacity of 3,560 tons of copper annually; and also owns a large smelting plant at Copper Cliff, possessing a capacity of 3,125 tons of ore per day.

In addition, the British-American Nickel Corporation has erected a smelter at Nickelton and an electrolytic refinery, using

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\* Described in Eng. and Min. Journ., March 8, 1919.

the Hybinette process, with a capacity of 4,000 tons of copper per annum at Deschenes (Quebec), 8 miles from Ottawa City, for the separation of the copper, nickel and precious metals such as platinum, palladium, iridium, etc., from the matte.

The Alexo mine, situated 150 miles north of Sudbury, in the Porcupine area, is remarkable as containing nickel although outside the Sudbury district. The ore-body occurs at the contact of peridotite (now largely altered to serpentine) with a pillow-lava which usually has the composition of andesite. The ore is of two distinct types representing two periods of deposition. The disseminated type appears to be an original magmatic segregation of the peridotite, while the solid sulphide type appears to have been introduced later through shrinkage cracks formed on cooling. The minerals occurring are pyrrhotite with smaller amounts of pyrite, chalcopyrite and pentlandite.

The average grade of the whole ore-body is about 4.5 per cent. of nickel with less than 1 per cent. of copper. The ore is self-fluxing.

The ore-body has been proved for a length of 700 feet and to a depth of 240 feet. The width varies from 3 feet to 40 feet, but the average is about 10 feet.

In the Massey district, the old Massey mine, discovered in 1900, was re-opened in 1917, and about 50,000 tons of ore, assaying 3 to 5 per cent. copper, were said to have been developed.

Other mines in Western Ontario: the Tip Top near Kasha-boilbe, and the Port Arthur at Mine Centre shipped ore in 1918.

In the Parry Sound district, on the eastern side of Georgian Bay, some surface development has been carried out. A shipment of 210 tons of selected ore from the McGowan mine is said to have returned 17 per cent. copper.

In the neighbourhood of the Algoma Central Railway, copper is stated to have been found in fissure veins from 10 to 70 feet wide, in the form of chalcopyrite with a little chalcocite. The ore is estimated to average 4 per cent. copper, 1 oz. silver and 0.4 dwt. gold per ton, and a large amount of development work has been done.

#### MANITOBA\*

Manitoba attracted much attention in 1916-17 by the discovery of large and rich copper deposits in the Flin Flon Lake district, 90 miles north-west of Pas on the Saskatchewan River.

The country rocks of this district resemble the Keewatin of Ontario, but their age is as yet uncertain. They consist of a thick series of sedimentary rocks, largely conglomerate, arkose and greywacke, associated with greenstones and gneiss. All these formations have been invaded by granite intrusions.

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\* Mining Development in Northern Manitoba, by R. C. Wallace; Trans. Can. Min. Inst. Vol. XXII. Amisk-Athapapuskow Lake District, by E. L. Bruce; Dept. of Mines, Canada, Geol. Surv. Memoir 105, 1918.

At Flin Flon the ore occurs in a foliated greenstone and in lenses of pyrite, zinc-blende, chalcopyrite and magnetite, associated with quartz-porphry dykes.

The ore-body of the Hammill mine is stated to consist of a mineralized shear-zone in massive greenstone, and to have been proved for 2,500 feet, with a width of 75 feet of solid sulphides. The Flin Flon ore-body, including solid sulphides and disseminated ore, is estimated to contain over 15 million tons, assaying 1.69 per cent. of copper, 3.49 per cent. zinc, with .082 oz. gold and 1.16 oz. silver per ton.

The Mandy mine at Schist Lake, 4 miles south-east of Flin Flon, has also been developed. In June, 1919, a sulphide ore-body had been developed for a length of 225 feet and a maximum width of 40 feet at the surface. The ore-body is lenticular and consists of disseminated sulphides on the walls with massive sulphides in the centre. A central mass of high-grade chalcopyrite which rested on the footwall has been mined. Between this and the pyritic ore on the hanging-wall there was a band of zinc-blende from 10 to 12 feet in width. The ore-body is in chloritic schists which alternate with greenstones, and the ore-deposition is connected with igneous intrusions which are found in the vicinity. The disseminated ores are considered to be replacement deposits in shear-zones, and the high-grade ore is believed to have been deposited at a later date in a fault fissure cutting through the disseminated ore. About 25,000 tons of ore, containing 19 per cent. copper with 2 dwt. gold and 2 oz. silver per ton, have been shipped to the Trail smelter; and a further 200,000 tons of ore have been developed, averaging 8 to 10 per cent. copper and 20 per cent. zinc with 2 dwt. gold and 2½ oz. silver per ton. Under present conditions of transport this ore is too poor to mine, but it is proposed to build a railway to the district and construct a smelter of 2,000 tons daily capacity. At present a year elapses between the time when the ore is mined and the time when it can be smelted at Trail.

\* About 20,000 h.p. can be obtained from Birch rapids on the Sturgeon-weir river for mining and smelting purposes, but in order to get a large supply it would be necessary to utilize the Bloodstone and Island falls on the Churchill river, rated at 27,300 and 49,000 h.p., which are 80 and 60 miles distant respectively.

#### BRITISH COLUMBIA

The Granby Consolidated Mining, Smelting and Power Company is at present the most important copper-mining undertaking in Canada, owning the Hidden Creek mines in the Nass River Division; the Phoenix group of properties in the Greenwood Division; and others in Washington Territory on the Granby Peninsula, on the Ecstall river and Prince of Wales Island,

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\* The New Manitoba District, Dept. of the Interior, Canada, by F. H. Kitto, 1918, p. 24.

and at Hadley, Kasaan Bay and Valdez in Alaska. The Company's smelters are situated at Grand Forks and at Anyox. The Phoenix mines comprise a mineralized area in which there are two distinct sets of ore-bodies, the Knob Hill Ironsides, and the Golden Drop. The geology is complicated, Palæozoic rocks, consisting of limestones and argillites, overlying beds of fragmental volcanic rocks, intensely altered by contact metamorphism. The ore-bodies occur in basin-shaped troughs in the zone of mineralization, and may be regarded as replacement deposits in the limestone carrying finely disseminated copper pyrites. In 1917, the Phoenix ore yielded slightly less than 17 lb. of copper per ton. The mines were developed to a depth of about 485 feet in the Victoria Shaft, and the total production of the Phoenix and Golden Drop may be put at about  $11\frac{1}{2}$  million tons of ore. In 1918, 277,628 tons of ore from all sources yielded 21.93 lb. of copper, 0.267 oz. silver, and 0.5 oz. gold per ton. Mining operations were stopped in June, 1919, partly on account of exhaustion of the ore-bodies, and partly in consequence of local labour difficulties. These mines are, however, reported to contain over  $2\frac{1}{2}$  million tons of low-grade ore, of which about 500,000 tons are still available, although the eastern section of the Camp may be regarded as being practically worked out. The Phoenix Camp has been in operation for some 20 years and has produced over 30,000 tons of copper and £700,000 in gold and silver. The principal mine of the group, the Golden Drop, produced 670,000 tons of ore before it was exhausted and yielded a profit up to 4s. a ton. The production of the whole group before the mines were abandoned is put at 1,575,624 tons of ore. The Grand Forks smelter,\* 24 miles south of Phoenix, has a capacity of 3,900 tons daily; it is the largest smelter in Canada and one of the largest in the world. The converter product is 98.5 per cent. blister copper containing an average of 20 oz. silver and 4.5 oz. gold per ton, which is sent to the Laurel Hill Works of the Nichols Copper Company for electrolytic refining.

The Hidden Creek or Anyox mines in the Nass River Division, south of the Portland Canal, are owned by the Granby Company and are probably the largest copper mines in the province. The claims are situated on a hill some 920 feet in height. The ore occurs as a mass of solid sulphides, pyrite and chalcopyrite, or mixed with country rock in "shear zones" up to 400 feet in width, in crushed and schistose rocks (schists, slates and limestones) lying upon granite, cut by dykes and highly metamorphosed. There are two principal ore-bodies, one from 100 to 250 feet wide and traced for some 1,500 feet, the other being about 400 feet wide and about 700 feet long. In places the ore-bodies enclose siliceous zones containing disseminated sulphides. The ore as proved by diamond drilling extends 300 feet below sea level, a vertical depth of 1,250 feet below the outcrop. The principal developments are by adits, the main adit being 450 feet

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\* Min. and Sci. Press, Feb. 24, 1917.



from the surface. The ore reserves at June 30th, 1917, were estimated at 16,196,146 tons, averaging 1·61 per cent. copper, 8,823,378 tons carrying 2·31 per cent. copper and 7,372,768 tons carrying 0·647 per cent. of copper.

In 1917 the Bonanza group, adjacent to Hidden Creek, was estimated to contain 807,460 tons of 1·6 per cent. ore, including 370,335 tons carrying 2·66 per cent. copper and 1s. 3d. in gold and silver per ton.

The Anyox smelter, owned by the Granby Company, is situated on Observatory Inlet, and was blown-in during the month of March, 1914. The plant at the present time is the largest "pyritic smelter" in the world, having a daily capacity of from 2,000 to 2,500 tons. An interesting detailed description of this plant is given in the Report of the Minister of Mines, British Columbia, for 1917.

A difficulty in dealing with the smelter production of Canada, from a statistical standpoint, arises from the fact that the copper produced from their Alaskan mines is included in the Smelting Company's production records, whilst other lots of ore are shipped by Canadian mineowners from Canada to the United States smelters at Tacoma and elsewhere.

Custom ore represented approximately 1½ per cent. of the amount of ore treated in 1916 by the Granby Company. In 1913, the production of the Granby group, chiefly from the Phoenix mines at Greenwood and the Hidden Creek mines at Anyox, was 1,142,740 tons of ore, which yielded 10,128 tons of copper, 324,336 oz. silver and 47,266 oz. gold. In 1919, the Hidden Creek mines supplied to the Anyox Smelter 647,466 tons of ore, which yielded 8,725 tons of copper, 4,864 oz. of gold and 348,408 oz. of silver. In the year ended June 30th, 1919, the Granby Company is stated to have smelted (in addition to custom ore) 881,218 tons of ore, yielding 12,595 tons of copper, 567,425 oz. of silver and 23,303 oz. of gold at a cost of 11½d. per lb. of copper.

The Canada Copper Corporation owns extensive properties located on the Mother Lode at Greenwood, and at Copper Mountain in the Princeton Section of the Similkameen Division, as well as other mines and a smelter at Lightning Peak Camp in the Greenwood Division. In the Mother Lode group, four miles from Greenwood, the copper ore occurs in a contact deposit between limestone and eruptive rocks, largely in altered limestones replaced by garnet, magnetite, silica, &c., together with iron and copper sulphides. The main ore-body measured about 160 by 1,200 feet, its maximum width being 260 feet. In 1916, 229,271 tons, averaging 0·945 per cent. of copper, and 0·038 oz. gold and 0·179 oz. silver per ton were produced, but the property appears to be nearing exhaustion, and operations were suspended in 1918. The Mother Lode is stated to have produced 137,796 tons of low-grade copper ore in 1918.

The construction of the West Kootenay power line from Greenwood to Copper Mountain, a distance of 100 miles, should give an

incentive to prospecting and reduce costs, fuel having hitherto been a serious item in working expenses in this district. The mines developed and worked by the Company on Copper Mountain are important and extensive. This mountain consists of a complex of various granitoid rocks, chiefly monzonite-porphry and granodiorite, and the ore-bodies are associated with a younger system of porphyry dykes. The ores consist of primary chalcopryite and bornite, filling numerous fractures and also disseminated in the porphyry and granodiorite, associated with hæmatite, magnetite and iron-pyrites. Along certain zones secondary action has taken place giving rise to chalcocite, native copper, malachite, azurite and cuprite. The rock-crushing mill is situated at Allenby, 9 miles from the mine, on the Similkameen river, where a pumping station is installed. The flow-sheet of the mill is given in detail in the Report of the Minister of Mines, B.C., for 1918, and its capacity is estimated at 1,800 tons per day. In 1918, the ore reserves were estimated at 10 million tons of developed ore and 2 million tons of probable ore, having an assay value of 1.74 per cent. copper and about 1s. 5½d. per ton gold and silver. A 40-ton flotation test mill is said to have given satisfactory results.

The Greenwood smelter of the Canada Copper Corporation in 1918 produced 1,256 tons of copper, 60,495 oz. of silver and 12,663 oz. of gold. It was closed down in November, 1918.

In the Skeena Division there were a number of mines undergoing development in 1918, but few of them appear to have reached the stage of developed mines. In the Coast Section the principal properties are the Belmont-Surf Inlet and Drum Lummon mines.

The Belmont-Surf Inlet property, situated on Princess Royal Island, is a gold-silver-copper proposition which has been extensively developed, the ore-reserves in 1917 being 344,036 tons. In September, 1917, the property was equipped with hydro-electric plant, 5.65 mile power-line, railway, compressor-plant, 300-ton concentrating mill and flotation machines. In 1919, approximately 92,791 tons of ore were milled, which produced 8,495 tons of concentrates, containing 51,684 oz. gold, 30,319 oz. silver and 361 tons of copper.

The Drum Lummon mine, also a gold-silver-copper proposition, is situated on Miskatlah Bay on the north shore of Douglas Channel, about 25 miles east of Hartley Bay. The deposit is said to be a shear-zone in granite, carrying bornite and copper-glance in a quartz gangue, but it has not as yet been opened up to any large extent. In 1919, 18 tons of concentrates were produced, yielding 8 tons of copper, 10 oz. gold and 353 oz. of silver.

During the year ended December 31st, 1919, copper-mining was carried on in the Queen Charlotte Division, at the Ikeda mines, on Moresby Island, which produced 135 tons of high-grade copper ore which were treated at the Granby smelter at Anyox, yielding 51 oz. gold, 722 oz. silver and 17 tons of copper.

In the Portland Canal Section of the Portland Canal Division, the old Brown-Alaska mine was operated for two years and shipped several thousand tons of copper ore to the Hadley smelter, averaging about 2·8 per cent. of copper. Developments in 1918 are reported to have exposed a quartz vein 14 to 19 feet wide, mineralized with pyrrhotite and chalcopyrite, carrying 2 feet of 5 per cent. copper ore on the hanging-wall, but the average is not thought likely to be more than 2 per cent. of copper.

In the Atlin Mining Division, there is an immense area of country practically unprospected, except along the lake-shores, from the Yukon boundary south to Taku Inlet and River, lying along the eastern contact of the Coast granites, which is probably as favourable a section for exploration as any in British Columbia. This division has produced but little copper in consequence of the high cost of treatment and transport, but one group of claims in the Rainy Hollow Section is reported to have shipped in 1918 22 tons assaying 39·83 oz. silver per ton and 22·32 per cent. copper. Bornite has been found on Mineral Mountain, in irregular veins up to 2 feet thick, in a zone of altered limestone intercalated with broad belts of slates and sandstone.

The principal producing mine on Texada Island, in the Nanaimo Division, is the Marble Bay, which has been developed to a vertical depth of 1,500 feet and from which regular shipments of copper-gold ore, approximating 9,000 tons, yielding about 280 tons of copper, were made in 1918.

The Vancouver Division occupies an area on the mainland as well as several small islands near the city of Vancouver, and contains the Britannia mine, which is the most important in the Western Mineral Survey District. During 1918, the Britannia Mining and Smelting Co. carried on work at the Fairview, Empress, Bluff, and Jane mines, Howe Sound. The properties which the Company controls have an average width of several hundred feet, and are situated along a mineralized belt extending for about 12 miles consisting of bands of metamorphosed sediments, with intrusions of granodiorite, and striking parallel with the axis of the Coast Range of mountains. The ore-bodies consist of a series of lenses of chalcopyrite and pyrite occupying fissures in schist. In 1919, 9 million tons of ore, averaging two per cent. copper, with low values in gold and silver, were reported as developed, without taking into account ore exposed by diamond drilling. The Company's property is completely equipped with machinery, driven by Pelton-wheels and steam turbines. In 1918, 652,056 tons are stated to have been milled at a cost of 8s. 3d. for mining, development and crushing, and 3s. 2d. for milling. Shipment of concentrates resulting therefrom amounted to 56,299 tons, assaying 14·53 per cent. copper, 3·32 per cent. zinc, 1·74 oz. silver and 0·053 oz. gold per ton. The copper production of the mines in 1913 was 5,878 tons; rising, in 1918, to 8,180 tons, containing 98,131 oz. silver and 3,045 oz. gold.

The Ladysmith Smelting Corporation, Limited, owns a smelter on Oyster Harbour, in the Vancouver Mining Division, which treated custom ore from as far north as Alaska and as far south as Mexico. In 1911, 37,527 tons of custom ore were treated. In 1918, the smelter was in operation for a few weeks, but closed down owing to shortage of ore supplies.

The Eastern Mineral Survey District is the oldest lode-mining district in British Columbia. In the Trail Creek Division, the most important copper-producing mines belong to the Consolidated Mining and Smelting Company of Canada.

The Le Roi-Centre Star group is situated on the southern slope of Red Mountain at Rossland. The country rock is considered to be a complex of Palæozoic volcanic rocks intruded into which is an elongated mass of porphyry. This is traversed by a nearly vertical series of basaltic dykes, from a few feet to 250 feet wide. The ore occurs in shoots from 3 to 50 feet in width, and 50 to 600 feet in length, widening where the veins and dykes intersect, but the larger dykes cut off the veins. The ore consists of highly auriferous and slightly argentiferous chalcopryite, associated with pyrite and pyrrhotite, carrying 0.5 to 2 per cent. of copper and from about 8 to 20 dwt. gold per ton. The gangue is siliceous altered country rock. In some cases the pay shoots extend from wall to wall, in others they merge into the country rock.

The Josie No. 1 and Annie mines are also situated on Red Mountain, and belong to the Le Roi No. 2 Company. The Josie mine has five principal veins, the ore of which is mostly chalcopryite, associated with pyrite and pyrrhotite in a siliceous gangue, averaging 2.25 per cent. copper, 0.5 oz. gold and 1.12 oz. of silver per ton; it has been opened up extensively from the main shaft, which is 1,300 feet in depth. In 1918, the Company produced 19,642 tons of ore, containing 300 tons of copper, 8,516 oz. of gold and 19,687 oz. silver. The mill has an estimated capacity of 50 tons a day.

The Trail Creek smelter is located near the International Boundary and treats various classes of Company and custom ores. The works are supplied with electric power from Bonnington Falls on the Kootenay River. The total production of the smelter from 1907 to 1919 is given as follows:—

Ore smelted	...	...	...	4,959,104 tons.
Gold	...	...	...	1,831,838 oz.
Silver	...	...	...	28,714,042 oz.
Lead	...	...	...	221,952 tons.
Copper	...	...	...	37,067 tons.
Zinc	...	...	...	20,026 tons

The production in 1919 is given as 3,096 tons of copper from 355,462 tons of ore.

In the North-eastern Mineral Survey district, the Omineca Division is the only one that appears to have produced copper in any quantity in 1918. The most important copper mine in the Hazelton Section is the Rocher Deboulé mine on Juniper Creek.

The ore occurs in parallel veins in sheared granite. The gangue is described as crushed and altered granodiorite, quartz, calcite and siderite, and the minerals are chalcopyrite, pyrite, pyrrhotite, arsenopyrite, galena, zinc-blende and tetrahedrite. The output in 1916 is given as 558 tons of copper from 9,000 tons of ore, and in 1918 it was estimated that 22,000 tons were blocked out, averaging 15 per cent. copper, 5.6 oz. of silver and 1.47 dwt. of gold per ton. The total production of the mine up to the end of 1918 was 35,565 tons of ore containing 4,214 oz. of gold, 62,865 oz. of silver and 2,565 tons of copper. In October, 1918, the mine was shut down until operating conditions became more favourable.

In the Central Mineral Survey District copper has been found in the Lillooet, Ashcroft, Nicola and Yale Divisions, but does not appear to have been developed to any large extent as yet, the Iron Mask mine, about 7 miles south-west of the City of Kamloops, being the only mine operating a reduction plant of any size. The mine has been developed down to the 750-ft. level and further prospected by diamond drilling. The deposits occur as lenses in a shear-zone, mineralized from 20 to 50 feet in width, the segregations of better-grade ore forming a pay streak of variable width, carrying chalcopyrite and magnetite in a chloritic gangue. The country rock is mainly diorite. The ore is difficult to concentrate by ordinary methods, and gravity-concentration plant has been discarded in favour of flotation.

In the Southern Mineral Survey District the Franklin Camp Section of the Grand Forks Division is notable on account of the presence of platinum in some of the ores, associated with copper minerals.

In the Eholt Section of this Division, the Emma mine shipped 18,993 tons of low-grade copper ore in 1919, valuable as a flux and containing 524 oz. gold, 730 oz. silver and 211 tons of copper.

The Smelting works of the Canada Copper Corporation are situated in the Lightning Peak Section of the Greenwood Mining Division, and have a smelting capacity of about 2,500 tons of ore per day. They also smelt custom ores. The Company's production of fine copper is stated to have been 2,320 tons in 1916, and 1,896 tons in 1917. The plant was closed down in the middle of November, 1918, but when the Company's mines on Copper Mountain are in full operation, it is expected that it will be re-opened.

The amounts of copper contained in the ores mined in the various mining Divisions of British Columbia in 1915 and 1918 are shown in the following table:—

Division	1915 (long tons)	1918 (long tons)
1. Skeena, Nass, Queen Charlotte and Port- land Canal ... ..	9,784	13,477
2. Grand Forks, Greenwood and Osoyoos...	7,769	4,438
3. Vancouver and New Westminster ...	4,044	7,834
4. Trail Creek ....	2,077	739

Division	1915 (long tons)	1918 (long tons)
5. Omineca ... ..	1,264	287
6. Vancouver Island, Nanaimo, Alberni, Clayoquot, Quatsino and Victoria ...	318	414
7. Yale, Ashcroft and Kamloops ... ..	132	235
8. Atlin, Liard and Stikine... ..	—	5
9. Fort Steele (East Kootenay) ... ..	—	1
10. Nelson and Arrow Lake ... ..	14	13
11. Similkameen, Nicola and Vernon ... ..	10	5
12. Slocan and Slocan City ... ..	—	1

In 1917, the Windermere and Golden Division produced 6 tons of copper.

The total copper production of British Columbia to the end of 1918 amounted to 374,106 tons, valued at £30,362,723.

#### YUKON TERRITORY

The chief copper mines in the Yukon Territory are the Pueblo and the Carlisle.

The Pueblo deposit is an irregular mass enclosed in crystalline limestone near a granite contact; 600 tons of ore shipped to the Crofton Smelter are stated to have contained 5 per cent. copper, 1.40 to 2.24 oz. of silver per ton and some gold.

The Carlisle mine is reported to have a vein 15 feet wide, with high-grade ore up to 4 feet in width, consisting of bornite and chalcopyrite.

#### NORTH-WEST TERRITORIES

North of Alberta, in the lower part of the Coppermine river, in the Bathurst Inlet area, an examination made by the Canadian Arctic Expedition showed that copper occurs native in the amygdaloidal form, running from 0.01 to 1 per cent. or over in an enormous tonnage of rock; and cutting through these rocks there are veins which contain thin sheets of native copper up to  $\frac{1}{8}$  inch in thickness, and others containing up to  $4\frac{1}{2}$  per cent. of flake copper. Part of the country, however, is at present difficult of access. J. B. Tyrrell, reporting on the copper possibilities of the far north, reported that: "The copper-bearing rocks would seem to extend along the Arctic coast both east and west of the Coppermine river for about 500 miles in all, and probably many of the smaller islands off the coast are also of the same rocks, and the total area of these rocks undoubtedly amounts to many thousands of square miles. Comparing the early accounts of the occurrence of native copper on Lake Superior with the accounts which we now possess of the copper on Coppermine river, and considering the enormous extent of the northern deposits, we have reasonable grounds for hope that before many years the Coppermine area will produce as much copper as is now mined in Northern Michigan."

*Copper content of ore mined in Canada*

(Annual Reports of the Mineral Production of Canada)

Year.	Quantity (long tons)				
	British Columbia	Ontario	Quebec*	Yukon	Dominion
1913 ...	20,443	11,556	1,543	823	34,365
1914 ...	18,402	12,923	1,876	610	33,811
1915 ...	25,309	17,572	1,874	238	44,993
1916 ...	28,412	20,088	2,546	1,253	52,299
1917 ...	25,773	19,137	2,239	1,098	48,762†
1918 ...	28,065	21,015	2,620	277	53,022‡
1919 ...	19,867	10,869	1,202	74	33,506§

\* Including the production from pyritic ores where the copper content is paid for.

† Including 515 tons produced chiefly in Manitoba.

‡ Including 1,045 tons produced chiefly in Manitoba.

§ Including 1,494 tons produced chiefly in Manitoba.

*Imports of Copper into Canada\**

(Annual Reports of the Mineral Production of Canada)

Year	Quantity (long tons)				
	Pigs, Ingots, or in Blocks	Old and Scrap	Bars, Rods, Sheets, Tube and Wire	Crude Precipitate	Copper Sulphate
1913 ...	2,372	266	15,670	2	910
1914 ...	1,667	57	10,009	1	510
1915 ...	2,130	31	6,877	1	828
1916 ...	1,539	43	9,840	4	805
1917 ...	2,642	52	10,663	10	1,409
1918 ...	2,118	275	7,573	†	1,228
1919 ...	1,358	451	4,865	‡	837

\* Excluding imports of nails, tacks, rivets, &c., wire cloth, &c. and other manufactures which are reported by value only.

† 1,000 lb.

‡ 50 lb.

*Imports of Copper in Blocks, Pigs or Ingots into Canada  
(For Consumption)*

*Fiscal years ending March 31*

† (Annual Reports on the Trade of Canada)

Year	Quantity (long tons)		
	From United Kingdom	From Foreign Countries*	Total
1913 ... ..	22	2,264	2,286
1914 ... ..	18	2,257	2,275
1915 ... ..	—	1,974	1,974
1916 ... ..	—	1,662	1,662
1917 ... ..	—	2,225	2,225
1918 ... ..	—	2,357	2,357
1919 ... ..	—	1,603	1,603

\* All from United States, with the exception of 25 tons imported from Germany in 1914.

*Imports of Part-manufactured Copper (in bars and rods, in coil or otherwise, in lengths of not less than 6 feet) into Canada  
(For Consumption)*

*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

Year	Quantity (long tons)		
	From United Kingdom	From Foreign Countries*	Total
1913 ... ..	316	13,333	13,649
1914 ... ..	9	12,057	12,066
1915 ... ..	—	6,463	6,463
1916 ... ..	—	5,957	5,957
1917 ... ..	—	8,446	8,446
1918 ... ..	—	8,512	8,512
1919 ... ..	—	7,407	7,407

\* All from the United States, with the exception of 1 ton imported from Germany in 1914.



*Imports of Copper (in strips, sheets or plates, not polished,  
planished or coated) into Canada  
(For Consumption)*

*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

Year	Quantity (long tons)		
	From United Kingdom	From Foreign Countries*	Total
1913 ... ..	46	1,954	2,000
1914 ... ..	15	1,766	1,781
1915 ... ..	4	1,495	1,499
1916 ... ..	—	1,140	1,140
1917 ... ..	15	1,151	1,166
1918 ... ..	10	913	923
1919 ... ..	—	592	592

\* All from the United States, except 1 ton imported from Germany in 1914.

*Imports of Crude Precipitate of Copper into Canada  
(For Consumption)*

*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

Year	Quantity* (long tons)			
1913 ... ..	...	...	...	3
1914 ... ..	...	...	...	2
1915 ... ..	...	...	...	—
1916 ... ..	...	...	...	—
1917 ... ..	...	...	...	4
1918 ... ..	...	...	...	10
1919 ... ..	...	...	...	0·4

\* All from the United States.

*Imports of Sulphate of Copper (Blue Vitriol) into Canada*  
*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
United Kingdom ... ..	568	353	120	273	211	—	—
Belgium ... ..	—	—	2	—	—	—	—
Germany ... ..	5	—	—	—	—	—	—
United States ... ..	562	243	582	575	690	1,247	1,128
Japan ... ..	—	—	—	—	5	—	—
Total from Foreign Countries	567	243	584	575	695	1,247	1,128
TOTAL ... ..	1,135	596	704	848	906	1,247	1,128

*Exports of Copper from Canada*

(Annual Reports of the Mineral Production of Canada)

Year	Fine in Ore, Matte, Regulus, etc. (long tons)	Black or Coarse Pigs, Bars, Sheets, etc. (long tons)	Old and Scrap (long tons)	Total (long tons)
1913 ... ..	36,553	344	1,115	38,012
1914 ... ..	30,728	2,938	887	34,553
1915 ... ..	36,356	9,506	1,858	47,720
1916 ... ..	55,778	1,085	2,610	59,473
1917 ... ..	38,641	7,844	7,051	53,536
1918 ... ..	32,766	20,884	400	54,050
1919 ... ..	18,237	8,121	1,392	36,659*

\* Including 8,909 tons of Blister Copper

*Exports of Fine Copper (contained in Ore, Matte, Regulus, etc.)  
from Canada (Domestic Produce)*

*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

Year	Quantity (long tons).		
	To United Kingdom	To Foreign* Countries	Total
1913 ... ..	2,404	33,733	36,137
1914 ... ..	3,038	34,127	37,165
1915 ... ..	4,939	23,042	27,981
1916 ... ..	6,140	34,397	40,537
1917 ... ..	6,456	50,013	56,469
1918 ... ..	6,044	28,570	34,614
1919 ... ..	4,734	24,557	29,291

\* All to the United States with the exception of 1 ton exported to Germany in 1914.

*Exports of Black or Coarse Copper, Cement Copper and Copper  
in Pigs from Canada (Domestic Produce)*

*Fiscal years ending March 31*

(Annual Reports on the Trade of Canada)

Year					Quantity* (long tons)
1913	...	...	...	...	1,213
1914	...	...	...	...	—
1915	...	...	...	...	4,403
1916	...	...	...	...	9,037
1917	...	...	...	...	—
1918	...	...	...	...	—
1919	...	...	...	...	—

\* All to the United States.

*Exports of old and scrap Copper from Canada  
(Domestic Produce)*

*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
United Kingdom ... ..	—	285	163	37	19	—	—
Germany ... ..	—	12	23	—	—	—	—
Italy ... ..	—	9	—	—	—	—	—
United States ... ..	—	988	757	2,527	3,719	5,000	1,428
Total to Foreign Countries	—	1,009	780	2,527	3,719	5,000	1,428
TOTAL ... ..	—	1,294	943	2,564	3,738	5,000	1,428

*Exports of Copper, Pigs, Bars, Sheets, etc., from Canada  
(Domestic Produce\*)*

*Fiscal years ending March 31*

(Annual Reports of the Trade of Canada)

To	Quantity (long tons)		
	1917	1918	1919
United Kingdom ... ..	19	7	—
Africa, South and West ... ..	—	—	12
Trinidad and Tobago ... ..	—	—	1
Hong Kong ... ..	—	—	6
India ... ..	—	10	—
Australia ... ..	—	—	23
Total to British Possessions ...	19	17	42
France ... ..	—	139	—
Italy ... ..	—	—	3
Portugal ... ..	—	—	1
United States ... ..	70	13,205	21,642
Brazil ... ..	—	—	4
Total to Foreign Countries ...	70	13,344	21,650
TOTAL ... ..	89	13,361	21,692

\* Not separately recorded prior to 1917.

### Newfoundland

Deposits of copper ore have been worked for a number of years in different parts of Newfoundland.

The Cape Copper Company formerly operated the Terra Nova mine, near Millertown, which is stated to have produced 5,600 tons of ore, assaying 2·41 per cent. copper and 37·23 per cent. sulphur.

In the Buchan's River mine, 5 miles from Red Indian Lake, in the central part of Newfoundland, copper ore is found in schists. The mine has been developed to a depth of about 370 feet. The ore-body varies from 5 to 10 feet in thickness and is about 350 feet long. The ore is a complex sulphide carrying about 2½ per cent. copper, 8 per cent. lead, 20 per cent. zinc, with 7½ oz. silver and about 3 dwt. gold per ton.

A property has been worked near Twillingate, in the vicinity of the Tilt Cove mine. The vein is claimed to be 160 feet wide, exposed for about half a mile in length, and tested to a depth of 200 feet, carrying chalcopryite associated with zinc-blende, and averaging 2 to 2·9 per cent. of copper, 50 per cent. of sulphur and 1½ dwt. gold per ton.

The Tilt Cove, or Union mine, is on the north side of the Bay of Notre Dame. The ore occurs in bunches of varying size, or permeating the softer and more slaty rocks. The country rock appears to be a chloritic schist, very ferruginous, with seams of serpentine, and having large intercalated masses of a hard, compact rock which is probably a volcanic ash. The total shipments from this mine are stated to have been 1,491,136 tons of ore, 78,015 tons of regulus and 5,418 tons of ingots.\*

The Betts Cove mine was opened in 1875 and produced in ten years 130,682 tons of ore and regulus, in addition to 2,450 tons of iron pyrites.

The Little Bay mine produced 10,000 tons of ore in 1878 and between 1885 and 1891 produced over 40,000 tons of regulus and ingots. This mine, like many others, closed down on account of the low price of copper. It has recently been re-opened.

Native copper occurs on the shores of Conception and Placentia Bays in small quantity, and on the island of Oderin, off the west coast of Placentia Bay, where much of the greenstone and amygdaloidal trap is impregnated with disseminated scales and particles of copper.

The Government financed an electrolytic refining plant at St. John's, which had an initial capacity of 125 tons a day in 1916, and made practically all the copper used locally for cartridges and shells. This assistance encouraged the owners of various small copper prospects to open up their properties, with such success that two new smelters were planned for Notre Dame Bay.

#### *Exports of Copper Ore from Newfoundland (Domestic Produce)*

*Fiscal years ending June 30*

(Newfoundland Customs Returns)

Year						Quantity† (long tons)
1914	...	...	...	...	...	13,797
1915	...	...	...	...	...	3,250
1916	...	...	...	...	...	9,405
1917	...	...	...	...	...	16,066
1918	...	...	...	...	...	5,087
1919	...	...	...	...	...	56

† Exported chiefly to the United States.

#### **Cyprus**

The island of Cyprus has been prospected for pyrites during the past few years. An important deposit has been found at Foucassa Hill, near Skouriotissa, in the district of Nicosia.

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\* Dominion of Newfoundland and Labrador, 1921.

The Skouriotissa ore-body has been proved by systematic drilling and is estimated to contain not less than 5 million tons of cupreous pyrites of good quality. An average analysis gives 47·5 per cent. sulphur, about 2·5 per cent. copper, 41·85 per cent. iron, and ·01 per cent. arsenic.

The deposit is near the seashore and a mineral railway connecting the mine and the coast has been constructed and equipped. A jetty has been built for loading the ore into barges by which it is to be transferred to vessels standing out in deeper water.

Indications of other deposits of the same kind are numerous in the south-western and southern parts of the island, but no other large body of high-grade ore has as yet been discovered.

According to the Colonial Report on Cyprus for 1920 (No. 1093), some 2,000 tons of cupreous pyrites were extracted during that year.

### India\*

Copper ores are known to occur in several localities in India, but the production of metallic copper on a large scale only commenced in August, 1918.

The Cape Copper Company, Ltd., has for some years been engaged in opening up the Rakah mine, in the Singhbhum district of Bihar and Orissa. This mine reached the producing stage in 1911, when an output of 2,079 tons of ore was obtained. In December, 1920, there were two shafts, 1,183 feet and 423 feet deep, respectively, and the driving and sinking on the deposit aggregated about 25,750 feet. The reduction plant is designed to produce 3,000 tons of refined copper per annum. The ores, which are stated to contain from 2 to 6 per cent. of copper, are either disseminated through the schists or form indefinite lodes coinciding in direction with the bedding-planes of the schists. At depth they consist of copper pyrites, the sulphide being changed near the surface into carbonates and oxides. The mines lie along a belt of country in which ancient copper mines have been traced at frequent intervals for over 80 miles.

Large bodies of argentiiferous copper-ore occur at the Bawdwin mines, in the Northern Shan States, Burma. The ore deposit is a replacement of rhyolite by an intimate mixture of sulphides, chiefly of lead and zinc; but, in addition, the deposit carries copper at its north end, and in September, 1920, 335,631 tons of this class of ore, averaging 23·1 oz. of silver per ton, 12·8 per cent. of lead, 7·70 per cent. of zinc, and 11·0 per cent. of copper, were stated to have been developed.

Copper ores have been found at a large number of localities in the State of Sikkim, where they occur among pre-Cambrian slates and schists, in the neighbourhood of intrusions of granite, but up to the present there has been no actual exploitation.

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\* Records of the Geological Survey of India. Indian Munitions Board Industrial Handbook, 1919. Reports, Chief Inspector of Mines in India (Annual).

*Production of Copper Ore in India*  
(Records of the Geological Survey of India)

Year	Quantity (long tons)	Estimated copper content* (long tons)
1913 ... ..	3,810	143
1914 ... ..	5,324	200
1915 ... ..	8,885	333
1916 ... ..	2,671	100
1917 ... ..	20,018	751
1918 ... ..	3,619	136
1919 ... ..	32,759	1,228

\* Taken as 3.75 per cent.

*Imports of Unwrought Copper into India\**

(Accounts relating to the Sea-Borne Trade and Navigation of  
British India)

Year	Quantity (long tons)
1913 ... ..	2,980
1914 ... ..	3,577
1915 ... ..	1,764
1916 ... ..	250
1917 ... ..	221
1918 ... ..	1,650
1919 ... ..	4,225

\* Excluding Government Stores.

*Imports of Wrought Copper into India\**

(Accounts Relating to the Sea-Borne Trade and Navigation of  
British India)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
United Kingdom ...	16,838	15,089	5,474	669	247	406	4,008
France ... ..	1,575	2,191	13	25	15	16	16
Germany ... ..	12,478	10,767	650	—	—	—	—
Japan ... ..	—	532	841	158	812	1,307	401
Other Countries ...	667	515	111	89	54	142	175
TOTAL ... ..	31,558	29,094	7,089	941	1,128	1,871	4,600

\* Excluding Government Stores.

*Imports of Old Copper for re-manufacture into India\**

(Accounts Relating to the Sea-Borne Trade and Navigation of British India)

Year						Quantity (long tons)
1913	...	...	...	...	...	106
1914	...	..	...	...	...	127
1915	...	...	...	...	...	139
1916	...	...	...	...	...	138
1917	...	...	...	...	...	94
1918	...	...	...	...	...	26
1919	...	...	...	...	...	68

\* Excluding Government Stores.

*Imports of Copper into India (Government Stores)**Fiscal years ending March 31*

(Annual Statement of the Sea-Borne Trade of British India)

Year				Unwrought	Wrought	Total
				Quantity (long tons)	Quantity (long tons)	Quantity (long tons)
1913	...	...	...	1,698	403	2,101
1914	...	...	...	1,674	440	2,114
1915	...	...	...	2,036	479	2,515
1916	...	...	...	5,588	549	6,137
1917	...	...	...	2,829	152	2,981
1918	...	...	...	3,680	275	3,955
1919	...	...	...	3,320	780.	4,100

*Exports of Copper from India*

(Accounts Relating to the Sea-Borne Trade and Navigation of British India)

Year				Quantity (long tons)		
				Copper Ore Domestic Produce	Copper Domestic Produce	Copper Foreign Produce
1913	...	...	...	400	239	218
1914	...	...	...	750	131	379
1915	...	...	...	877	47	61
1916	...	...	...	—	582	435
1917	...	...	...	—	297	98
1918	...	...	...	—	11	28
1919	...	...	...	—	.81	284



### Australia\*

The Australian Commonwealth is the seventh largest producer of copper in the world, ranking, in 1918, next in importance to the United States, Chile, Japan, Mexico, Canada, and Peru. It has vast unprospected areas that offer great possibilities of additional production. Copper is produced in all the States, but the principal producing centres are in New South Wales, Queensland, South Australia and Tasmania.

The copper ores of Australia are chiefly treated by direct smelting or by concentration, the product from the latter being then smelted. The matte produced is either converted into blister copper on the mines or sent to the refineries for further treatment. There are four refineries operating in the Commonwealth, at Port Kembla and Eskdale, New South Wales; at Wallaroo, South Australia; and at Bowen, Queensland.

Strikes extending over long periods, and high rates of wages, have considerably interfered with production in recent years. At the end of June, 1921, every copper mine in Australia was closed down, but more recently the Wallaroo and Moonta mines have re-opened.

A Commission appointed to investigate the metal situation in Australia recommended in its Report† that bounties be granted at the rate of £3 per ton on all copper or brass plates, sheets and bars, and at the rate of £5 per ton on all copper or brass pipes, tubes and wire, manufactured in Australia from copper produced and refined within the Commonwealth, for a period of not less than five years. In order to prevent the undue inflation of the cost of refining against the mining companies, the Commission suggested that the prices charged for treatment by the refining companies should be subject to supervision.

An embargo was placed during the war on the exportation of minerals and metals, including copper ores, matte and blister.

### NEW SOUTH WALES

Many of the ores mined in this State are rich in copper and also contain gold and silver. It was stated, in 1916, that at one mine in the Goulburn Division of the Southern Mining District any ore containing less than 7 per cent. of copper was used for stope-filling.‡ In New South Wales picked surface-ores often contain from 16 to 20 per cent. or more of copper.

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\* Annual Reports of the Department of Mines, New South Wales. Annual Reports of the Secretary for Mines, Victoria. Annual Reports of the Under-Secretary for Mines, Queensland. Mining Review of South Australia. Reports of the Department of Mines, Western Australia (Annual). Reports of the Secretary for Mines, Tasmania (Annual). Annual Reports of the Administrator of the Northern Territory. Annual Reports of Papua. Communications to the Bureau from the Australian Metal Exchange. Queensland Geol. Surv. Mineral Index, 1912.

† Australian Copper Policy; The Mining Magazine, Vol. XV, 1916, p. 92.

‡ Ann. Rept. Dept. Mines, 1916, p. 49.

The most important copper-mining undertaking in the State has been the Great Cobar, Ltd., whose operations were suspended in March, 1919. This company owned, not only copper mines and smelter, but also coal mines, coke works, and electrolytic refining plant, in various localities of the State. From 1876 to the end of 1917, the mines of the Great Cobar group produced a total of 108,390 tons of copper, from which 277,238 oz. of gold and 1,456,985 oz. of silver were recovered. The ore-bodies occur as replacement veins from 10 to 120 feet in width, in Silurian sandstones and schists, the ore being essentially a cupriferous pyrrhotite. In 1913, the Great Cobar ore reserves were estimated at 2,705,161 tons of which 2,081,735 tons contained 2·5 per cent. of copper, with important quantities of gold and silver and of bismuth, which gave much trouble before electrolytic refining was adopted. In 1918, the production of copper amounted to 2,415 tons, valued at £217,350. The mine had been developed by a main shaft 1,540 feet in depth, and the smelting plant had reached a capacity of 1,800 tons per day, when the works were closed down in April, 1914. Smelting was resumed in January, 1916, but operations were finally suspended in March, 1919.

The Abercrombie copper mines at Burruga, formerly worked by the Lloyd Copper Company, have also produced a large amount of copper, but operations have been affected by scarcity of water, a condition which it was hoped to remedy by the construction of a storage reservoir with a capacity of 85 million gallons, or nine months' supply. This mine produced 300 tons of copper valued at £29,998 in 1918. The main vein traverses diorite and has an ore-shoot 700 feet in lateral extent with an average width of 5 feet. The mine has reached a depth of about 700 feet. The equipment includes steam and electric power-plants, concentration plant, roasting and reverberatory furnaces, converters, a Minerals Separation flotation plant for the treatment of accumulated tailings and machinery for briquetting concentrates. The mine is stated to have produced 389,221 tons of ore, yielding 15,812 tons of fine copper.

In 1918, the most important copper mines in New South Wales, other than those already mentioned, were the Mount Royal mines, Tottenham, which produced 182 tons of copper valued at £15,856; and the Mount Hope mine (about 100 miles south of Cobar), which produced 299 tons, valued at £31,667.

The C.S.A. mines are situated 7 miles north of Cobar and contain a number of irregular impregnation deposits in slates and sandstones. The leached gossan is barren to a depth of 450 feet from surface and is then followed by rich secondary deposits of lead-carbonate ores which are succeeded by secondary enriched copper ores. The primary sulphides, at a lower depth, consist of cupriferous pyrites with varying quantities of galena and zinc-blende, together with very low values in gold and silver. The ore is smelted to blister copper at the mines and an electrolytic refinery is being erected at Kandos with a capacity of 2,500 tons of electrolytic copper per annum. The output of the C.S.A.

mines in 1918 was 2,232 tons of copper valued at £223,200. The mine was closed down in 1919 but subsequently re-opened. In 1920 a fire occurred underground, necessitating a complete shut-down not only of the C.S.A. mines but also of other mines in the neighbourhood which were dependent on the C.S.A. smelter for reduction of their ores.

A considerable amount of copper precipitate is produced. In the Blaney Division of the Bathurst Mining District 26 tons of precipitate, valued at £2,203, are stated to have been recovered in 1916, from one mine.

A deposit of cupriferous pyrites has been developed in the Lewis Ponds mine, in the Orange Division of the Bathurst District. The ore is treated at the Cockle Creek Works for the manufacture of sulphuric acid and artificial manures, etc. In 1916, the output amounted to 5,300 tons.

In addition to the copper-smelting works in the Cobar, Burraga and Nymagee Divisions, there is a large copper-smelting and refining plant at Port Kembla, near Sydney, belonging to the Electrolytic Refining and Smelting Company of Australia, Limited. The "E.S.A." brand of copper, produced at Port Kembla, has a high reputation, and an increased quantity of this copper is being consumed annually in Australia in industries requiring a very high grade of copper. The production of copper, gold and silver from Australian ores at Port Kembla has shown a continuous increase during the period under review. In 1920, 1,290 tons of copper were produced from New South Wales ores.

#### VICTORIA\*

There appears to have been no production of copper ore in this State during the period under review, except in 1913, when an output of 41 tons was reported. The total recorded production of the metal is 18,730 tons.

Copper is found in Victoria principally as disseminated sulphide, or as solid veins of sulphide associated with hornblendic dykes. At Thompson River, the ore has been oxidized at the surface, and lies either within the dyke or between the dyke and the Silurian strata which it penetrates. Platinum and palladium also occur in appreciable quantities in association with the copper sulphides, both in the lode and in the dyke. At Mount Deddick, in East Gippsland, sulphide ore and some carbonates of copper occur in lodes and dykes in granodiorite. Other copper-bearing localities are Dark River, Heathcote, Bethanga and Cassilis.

#### QUEENSLAND

At the present time this is the most important copper-producing State of the Commonwealth. The output is obtained mostly from the Cloncurry district, North Queensland, and the Mount Morgan

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\* Econ. Geol. and Resources of Victoria, Bull. 34, Geol. Surv. of Victoria (1914).

mine, 25 miles from Rockhampton. The chief producers in the Cloncurry district have been two groups of mines, one owned by Mount Elliott, Ltd., the other by the Hampden-Cloncurry Copper Mines, Ltd. The high cost of materials, enhanced wages, industrial troubles, and difficulties in connection with the sale and shipping of copper seriously affected the production of these mines during the war, and smelting was suspended by the Hampden-Cloncurry Company from December, 1918, to September, 1919. The Mount Elliott Company suspended smelting operations in March, 1919. In January, 1921, it was announced that, owing to the unsatisfactory price of copper, every copper mine in the Cloncurry district was idle.

The ore in sight and partially developed above present workings in the principal mines owned by the Mount Elliott Company was estimated in 1918 as follows :—

			Tons	Copper per cent.
Mount Elliott	...	...	600,000	3
Mount Elliott	...	...	10,000	10
Hampden Consols...	...	...	450,000	4
Great Australia (lime)	...	...	110,000	2·5
Great Australia (jasper)	...	...	93,000	4·0
Dobbin	...	...	70,000	5·0
Mount Oxide	...	...	300,000	10·0
Argylla	...	...	200,000	4·0
Lady Leases	...	...	28,000	5·0
			<hr/> 1,861,000	<hr/> 4·64

At 30th June, 1919, the ore reserves were estimated at 1,876,000 tons, including 304,000 tons, containing 10 per cent. of copper; 119,000 tons, containing 5 per cent.; 743,000 tons, containing 4 per cent.; and 600,000 tons, containing 3 per cent. The Company's smelting plant has a capacity of 700 tons of blister copper per month, and a refinery has been erected at Bowen for the treatment of this product. During the financial year ended 30th June, 1918, 51,952 tons of ore were treated for a yield of 2,322 tons of blister copper, and in 1918-19, 61,975 tons yielded 2,884 tons of refined copper, smelting being suspended before the end of that financial year. The small mines in the vicinity of Mount Elliott benefit considerably by the Company purchasing ore containing over 5 per cent. of copper, obtained chiefly from old dumps.

The Hampden-Cloncurry Company owns a number of copper mines, and its equipment includes mining, milling and flotation plants, and a smelter with a capacity of 375 tons of ore per day. In August, 1920, the ore reserves were estimated at 172,100 tons, containing 9,050 tons (or 5·2 per cent.) of copper, from 3,000 to 4,000 tons of high-grade ore containing from 400 to 500 tons of

copper, and from 60,000 to 70,000 tons containing from 2 to 3 per cent. of copper. The production of the group during the period 1916-1919 was as follows :—

	Ore		Production	
	Smelted (tons)	Copper (tons)	Silver (oz)	Gold (oz)
1916 ... ..	104,476	7,525	59,119	2,234
1917 (6 months only) ...	46,443	312	23,418	1,028
1918-19 (12 months) ...	106,168	6,604	31,570	3,504

In the north-western part of the district, there is a group of mines and "prospects," including the Mount Cuthbert, the ore of which is estimated to average 8 per cent. copper. In 1920, the ore-reserves were estimated at 193,500 tons, containing 6·8 per cent. of copper. The Mount Cuthbert Company owns a 250-ton smelter, started in blast in 1917, and up to the end of February, 1919, a total of 91,855 tons of ore had been smelted, yielding 5,026 tons of blister copper. Most of this ore was treated at Mount Cuthbert and the remainder (about 13,000 tons) at Mount Elliott.

The returns of the Cloncurry field for 1918 show that 189,219 tons of copper ore were treated at the various smelters in the district for a yield of 11,525 tons of copper, valued at £1,278,785; 19,362 oz. of silver, valued at £3,792; and 3,851 oz. of gold, valued at £16,359.

The Herberton field has yielded minor quantities of copper and silver ores, and the Etheridge field contains a number of copper "prospects."

Some of the mines in the Chillagoe district are said to contain considerable reserves of copper ore, but the closing of the Chillagoe smelter in March, 1914, brought to an end the extensive development which was being carried on in this district. The ore deposits of the Cardross area are, in general, neither of great size nor of high grade, the sulphide ores averaging not more than 7 per cent. copper. The principal ores are chalcopryrite, bornite, and chalcocite. The presence of gold in the ores has been an important factor in the prospecting and exploitation of the lodes. The ore of the Clansman mine contains from 4 to 20 dwt. of gold per ton. The production of the Mammoth Copper Mine amounted in 1915 to 8,090 tons of  $7\frac{1}{2}$  per cent. ore, yielding 591 tons of copper, 29,179 oz. of silver and 969 oz. of gold.

In 1913, Chillagoe, Ltd., bought the Einasleigh Freehold Copper Mine, in the Etheridge field, which became the chief source of supply for the Chillagoe smelters in that year. The production for the first ten months of 1913 amounted to 22,480 tons of ore. The ores consist of pyrrhotite and chalcopryrite, with a little native copper, and from 1909 to 1913 the ore despatched to the smelters averaged 6·17 per cent. copper.

Deposits of copper ore have also been worked in the Gympie, Gladstone, Mackay, Charters Towers, and Stanthorpe districts, and in the Mount Perry and Claremont fields, but so far the

quantity of ore developed has been unimportant. Copper ore from the Pinnacles mine is treated at a small smelting works at Ravenswood, Charters Towers district, and ores from the Mount Perry Company's mines are smelted locally.

The Mount Morgan gold mine, situated in the Rockhampton district of Queensland, is now primarily a copper-producer, the auriferous gossan originally worked having been found to be the capping of a great copper deposit. Copper smelting commenced in 1906, and the gold reduction furnaces were closed down in 1912. In 1916, a wet-concentrating plant and flotation units were installed and the amenability of the ores to leaching is now being investigated. From 1883 to October, 1918, the mine produced 4,637,421 oz. of gold and 86,678 tons of copper. In the year ending 29th May, 1921, 5,149 tons of copper and 76,463 oz. of gold were recovered. At the same date the ore reserves were estimated at 3,257,287 tons, containing 2.57 per cent. copper and 6.04 dwt. of gold per ton.

At Glassford,\* in the Gladstone district, contact metamorphic deposits have been developed, containing chalcopyrite, bornite and occasionally chalcocite in a matrix of garnet-rock and magnetite.

#### SOUTH AUSTRALIA

Copper ore is widely distributed in South Australia, the principal producing field being that of Wallaroo and Moonta, on Yorke Peninsula. Many other deposits exist in the Mount Lofty Ranges, the Flinders Range, Eyre's Peninsula and in the Dennison Range (close to the northern railway and west of Lake Eyre). They are almost entirely confined to the pre-Cambrian and Cambrian rocks.

A large proportion of the copper ore hitherto won consists of cuprite, malachite, atacamite and chalcocite obtained from shallow depths. The deep mines of Wallaroo and Moonta, however, produce sulphide ores from veins, some of which have a well-defined pegmatitic character.

Many of the smaller mines of the Flinders Range have produced rich hand-picked ore, and attention is now being directed to some of the large low-grade deposits.

Promising discoveries have been made recently to the south-west of Marree and to the north of Olary and in the Yelta district.

At the north-western end of Pernatty Lagoon there are carbonate, silicate and sulphide ores impregnating sedimentary deposits.

In the Kitticoola mine, south of Palmer, and in the Lux mine, east of Olary, gold occurs associated with copper pyrites in siliceous lodes, but the treatment of the ores is difficult.

Copper vanadate occurs in many of the northern lodes. A peculiar feature of some of the lodes of the Flinders Range, due

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\* Queensland Govt. Min. Journ., 1920, Vol. XXI, pp. 455-460.

to arid climatic conditions, is the superficial hardening of the outcrops with silica associated in some cases with a small proportion of malachite.

The Wallaroo mine was started in 1860 and the Moonta mine in 1861, the two mines being amalgamated in 1889. During their most productive period South Australia ranked first as a copper-producer in the Australian continent. The Wallaroo lodes traverse schistose rocks of sedimentary origin, while the Moonta lodes occur in porphyry.\* The ores consist of chalcopyrite, pyrite and pyrrhotite, with a little galena, blende and gold, the average copper-content for some years past being 3·85 per cent.

The Wallaroo main lode has been developed for about 3,400 feet laterally and 2,900 feet in depth. At Moonta the main lode extends for 3,840 feet and has been developed to a depth of 2,520 feet. The workings of the Wallaroo mine represent 38 miles of sinking, drifting, etc., while those of the Moonta total about 40 miles. Up to 30th June, 1920, approximately 11,327,000 tons of ore, averaging 3 per cent. copper, were produced at these mines. The yield of copper smelted was 324,160 tons, valued at about £19,765,000.

The "Wallaroo" brand of copper (99·66 per cent.) was at one time in great demand for special purposes, and though for many of these it has now been replaced by electrolytic copper, there still remain certain uses for which it is said to be preferred to other brands.

The works are situated on Wallaroo Bay, on the west coast of Yorke Peninsula. A calcining plant deals separately with crude ore, jigged concentrates and fines, the ore being smelted in reverberatory furnaces and the product treated in the refinery, which has a total capacity of 9,000 tons of refined copper per annum. Most of the copper is furnace-refined, but there is also a small electrolytic plant.

The gold in the roasted matte is brought up to 2 to 6 oz. per ton by "bottoming," and the copper free from gold is cast into (1) ingots weighing 14 lb., (2) medium cakes weighing about 40 lb. (made specially for the Indian Mints at Calcutta and Bombay and for the Cassipore Shell Foundry), and (3) cakes weighing 1 cwt.

Copper-sulphate works, capable of producing from 500 to 600 tons of sulphate per annum, and sulphuric acid works with an output of about 5,000 tons of chamber acid per annum, form subsidiary departments. The mines and smelter were closed down at the beginning of 1921 owing to high cost of production and low price of copper. They have recently been re-opened.

In 1918, prospecting operations and diamond drilling were undertaken by the Mines Department at the Yelta and Paramatta mines with important results, and discoveries of high-grade ore

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\* Wallaroo and Moonta Mines and Smelters. Descriptive pamphlet issued by the Company in 1920.

in the Tank lode indicate that further prospecting of the district might result in new discoveries, although such work is difficult owing to the obscuring of outcrops by soil.

### WESTERN AUSTRALIA

Copper ores are plentifully distributed throughout the State but have only been worked to any considerable extent in a few districts. The principal sources of copper are Northampton, West Pilbara, Mount Morgans and the Phillips river. The outputs of the various districts to the end of 1919 are shown in the following table :—

	Total to end of 1919		
	Ore (tons)	Metallic copper (tons)	Value (£)
Pilbara Goldfield ... ..	33	5	386
Nullagine District ... ..	5	2	120
West Pilbara Goldfield ... ..	79,480	10,425	690,075
Ashburton Goldfield ... ..	351	97	6,408
Peak Hill Goldfield ... ..	979	339	30,811
East Murchison Goldfield ... ..	239	39	4,364
Murchison Goldfield ... ..	968	131	10,714
Day Dawn District ... ..	56	8	522
Yalgoo Goldfield ... ..	38	6	413
Northampton Field ... ..	136	36	1,992
Yandanooka Field ... ..	172	28	1,889
Mount Margaret Goldfield ... ..	47,860	4,448	230,846
North Coolgardie Goldfield ... ..	6	1	51
East Coolgardie Goldfield ... ..	51	6	330
Phillips River Goldfield ... ..	95,320	8,287	581,561
Other localities ... ..	128	30	1,958

The Whim Well copper mine in the West Pilbara field has been the most important copper mine in Western Australia. The lode occurs in slates traversed by dolerite dykes and contains lenticular masses of ore consisting of carbonates and oxides of copper with bunches of chalcocite. A new process for leaching the dumps of oxidized ore has recently been attempted.\*

The principal mines of the Phillips River Goldfield are the Elverdton at Mount Desmond, and the Mount Cattlin at Ravens-thorpe. The lode or ore channel at the Elverdton mine is a crushed basic dyke impregnated with copper, and having a length of about a mile and a width of about 400 feet. In the upper levels the ore consists of ferruginous carbonate of copper associated with quartz. Below water level chalcopyrite and iron-pyrites occur.

The Eulamina copper mines in the Mount Morgan district of the Mount Margaret Goldfield have been important copper

\* Report on the Whim Well and Mons Cupri Copper Mines, by T. Blatchford Western Australia Mines Dept., 1921.



producers. The lode occurs in a fine grained greenstone, in a shattered belt of country in which the ore occurs in irregular masses. The copper minerals above water level are largely oxidized.

In 1918 the Phillips River Smelting Works treated 5,453 tons of ore for a yield of 338 tons of copper, 4,142 oz. gold and 3,443 oz. silver, representing a recovery of 6.19 per cent. of copper, with 12.6 dwt. of gold and 15 dwt. of silver per ton.

#### TASMANIA.

Tasmania is an important producer of copper, but is remarkable in possessing few known deposits of copper ore outside the Mount Lyell district. This is no doubt largely due to prospecting difficulties, the interior of the island being densely forested. The production in 1918 showed a decrease, as compared with that for the previous year, but this was largely due to a shortage of labour.

The Mount Lyell Mining and Railway Co., Ltd., is the principal producer, its mines being situated at Gormanston, on the west coast. The deposits occur along a schist-conglomerate contact. The ore-body is a lenticular mass, 270 feet in width by 660 feet in length on the No. 4 level, with a proved depth of 685 feet. This lens originally contained some  $6\frac{1}{2}$  million tons of ore. The ore is a clean, slightly cupriferous pyrite, containing a little lead and a trace of zinc, and, as now being mined, averages 0.53 per cent. copper, with 1.25 to 1.96 oz. silver, and 0.04 oz. gold per ton. The copper occurs in the form of chalcopyrite and tetrahedrite disseminated through the pyrite. One end of the ore-body is enriched from the surface to the bottom of the lens by an admixture of chalcopyrite and bornite with a little chalcocite. The five upper levels have been obliterated by a great open-cut, from which ore is being extracted in a series of benches carried to a depth of 450 feet, about 2 million cubic yards of capping being thus in course of removal. It is estimated that about one million cubic yards of ore will be available below the depth mentioned when this work has been completed.

The combined ore-reserves in the Mount Lyell and South Mount Lyell mines were estimated, on September 30th, 1920, at 1,802,509 tons, containing 0.50 per cent. of copper, with 1.5 oz. of silver and 0.04 oz. of gold per ton; while those of the North Mount Lyell mine were estimated at 1,013,518 tons, containing 6 per cent. of copper, 1.33 oz. of silver, and 0.005 oz. of gold per ton, as against 960,242 tons of the same grade in 1919. The pyritic ores of the Mount Lyell mine (which contain only a small amount of gangue) and the acid (siliceous) ores of the North Mount Lyell mine, are natural fluxing complements of one another.

The ore of the North Mount Lyell mine is disseminated through a highly quartzose schist in the neighbourhood of a conglomerate contact, the shoots of ore occurring as pipes or columns of irregular section in the recesses of the highly contorted contact surface of the conglomerate. The ore is mainly

bornite, but there are minor amounts of chalcopyrite and chalcocite, and a little pyrite. The main ore-body, which outcrops at the surface, has been proved to a depth of 1,000 feet. What is known as the "new-development" ore-body branches from the main ore-body on the 400-foot level, dipping steeply, and carries disseminated bornite of good grade to the 1,200-foot level, the deepest working in the mine. Chalcocite appears to be increasing in quantity with depth.

The Lyell Tharsis mine, an adjoining property acquired by the Company, is worked for ore of the same mineralogical character as the North Mount Lyell, but of much lower grade.

The South Tharsis and Royal Tharsis carry chalcopyrite and pyrite disseminated sparingly in schist, and the ore, although of very low grade and not amenable to ordinary gravity concentration, will, it is believed, be mined at some future time for concentration by oil-flotation.

The Mount Lyell Comstock mine, contiguous to the North Mount Lyell, has been re-opened and worked on a steadily increasing scale, the ore being concentrated by flotation. The ore is more basic than that of the North Mount Lyell, although similar to it in the southernmost section, where the two leases adjoin.

The Mount Lyell Company owns silica and limestone quarries, saw-mills for the supply of mine-timber and lumber, an aerial tramway ( $1\frac{1}{2}$  miles in length and having a daily capacity of 750 tons) between the mine and the smelter, and 4,500 feet of surface tramway, with counter-balanced cars connecting with a  $\frac{3}{4}$ -mile steam railway. A narrow-gauge line, about 7 miles in length, connects the mines and works, and, in addition, the Company owns two railway lines, one, 22 miles in length, connecting the reduction works at Queenstown with the seaport of Strahan, the other, 25 miles in length, connecting Gormanston with Kelly Basin near the head of Macquarie Harbour.

The Company's large hydro-electric plant is situated at Lake Margaret.

The first successful pyritic smelting was developed at the Mount Lyell plant in 1896, but the blast-furnaces have been greatly modified and improved since that date. The present No. 2 smelter has four 54-inch by 210-inch blast-furnaces with cast iron water jackets suitable for pyritic smelting, and with special mechanical feeders and hydraulic lifts. The charge averages 2.5 per cent. copper, and is brought to a matte of 40 to 50 per cent. The slags average about 0.33 per cent. copper, 32 to 38 per cent. silica, 42 to 52 per cent. iron protoxide, and about 4 per cent. calcium oxide. The amount of coke in the charge was formerly as low as 1 per cent., but is now from 3 to 5 per cent. in consequence of a reduction in the percentage of iron sulphide in the ore, and an increase in the zinc and lead. The new converter-plant is of the Great Falls upright type, electrically operated.

Concentrates and flue dust are treated by the Dwight-Lloyd sintering process. A flotation plant was completed in September, 1916, and up to April, 1917, 5,503 tons of ore from the Lyell Comstock, averaging 3·04 per cent. of copper, with 0·19 oz. of silver and 0·03 oz. of gold per ton, and 1,458 tons of ore from North Mount Lyell, averaging 3·06 per cent. of copper, had been treated, the concentrates obtained assaying 8·97 per cent. of copper. The recoveries were 89 per cent. of the copper, 74 per cent. of the silver, and 67 per cent. of the gold. The flotation plant treats about 100 tons of 3·43 per cent. ore daily, recovering 90 per cent. of the copper and making a 10 per cent. concentrate.

The Mount Lyell pyritic ore, won by open-cast working, costs about 3s. 6d. per ton, inclusive of 2s. per ton for removal of overburden; the ore won underground costs about 6s. per ton, while that from the North Mount Lyell mine costs 14s. per ton. From 1896 to 1913 the average cost of mining, smelting and converting was 22s. 10d. per ton, although for the six years ended 1909, the costs amounted to only 14s. 10d. per ton. Owing to increased underground work and prices of supplies these costs rose from 23s. 6d. per ton for the half-year ended March 30th, 1916, to 35s. 3d. in 1919, and to 45s. 5d. in 1920.

The final product obtained is blister copper, averaging 98·86 per cent. copper, with about 42·89 oz. silver and 1·11 oz. gold per ton. The silver contents have declined about 20 per cent. and the gold 40 per cent. in recent years. The blister copper is treated at the works of the Electrolytic Refining and Smelting Co., of Australia, Ltd., near Sydney. The total production of the Company to September 19th, 1917, was 7,168,348 tons of ore, yielding 162,600 tons of fine copper, 12,574,276 oz. of silver, and 365,298 oz. of gold. In the year ended September 30th, 1920, 4,536 tons of fine copper, 168,109 oz. of silver, and 5,164 oz. of gold were produced, as against 5,314 tons of copper, 266,864 oz. of silver and 5,538 oz. of gold in the previous year.

The Mount Lyell enterprise has had to contend with a series of financial, mining and metallurgical problems, which have been successfully solved. The heavy rainfall in Tasmania, averaging 110 inches yearly, has been a serious difficulty in working the mine by the open-cast method, but there is comparatively little water to be dealt with underground. The Company's operations include the mining and smelting of copper ore and pyrite in Tasmania, the manufacture of sulphuric acid and superphosphates in Victoria and Western Australia, and the production of coke in New South Wales.

#### NORTHERN TERRITORY

This region embraces a wide area, most of which lies within the tropics, and a large part of it is consequently unexplored.

Subsidies are granted by the Government for prospecting, shaft sinking and purchase of machinery. Copper ore has been found in several localities, but up to the present time no copper mines of any importance have been developed.

## PAPUA\*

The satisfactory price of copper, and a promise by the Commonwealth Government of a loan for a railway from Port Moresby to Sapphire Creek, created a renewed interest in the Astrolabe Copper Field in 1912-13, and a considerable amount of successful development work was carried out on the Dubuna and Laloki leases.

J. E. Carne, Assistant Government Geologist of New South Wales, in "Notes on the Occurrence of Coal, Petroleum, and Copper in Papua," states:—

"The visible supply of wholly or partially oxidized and enriched ores is too limited for serious consideration in estimating the possibilities of the field. So far as prospecting and development have proceeded, it is abundantly clear that the future of the Astrolabe copper industry is entirely dependent on low-grade pyritic ores. It is satisfactory, therefore, to note that, though copper values are undeniably low, the composition of each deposit on the Laloki, Tobo, Dubuna No. 2 lode, Mount Diamond, and Elvina mines is eminently suitable for semi-pyritic smelting—the most rapid and economic reduction process. Quantities, however, have yet to be proved; it is imperative that these should be demonstrated before smelting be considered."

Steady development work was carried on in the year 1917-18 on the Laloki and Dubuna leases, and a new find on the copper belt, which appears to extend eastwards, was made near Kapakaka. The Laloki mine was preparing to ship ore from Port Moresby in large quantities. The total amount of ore raised during the year was 7,170 tons. It was estimated that the reserves on the property amounted to 319,000 tons, containing 4.6 per cent. of copper and 2.5 dwt. of gold per ton. The Dubuna mine shipped 758 tons of ore, valued at £7,893. In 1919, considerable development work was carried out at both the Laloki and Dubuna mines, and a railway was under construction from Bootless Inlet to the mines. Extensive preparations were in progress for erecting a smelter, to produce blister copper, and for provision of shipping facilities at Bootless Inlet. Shortage of native labour has retarded development.

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\* Papua: Ann. Repts. Geology of Papua by E. R. Stanley, Govt. Geologist.

*Production of Copper in Australia\**

(Statistical Report of the Australian Metal Exchange, 1921)

	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
New South Wales...	8,805	4,578	3,211	5,053	6,513	6,005	1,531
Queensland ...	23,655	18,435	19,704	19,519	19,062	18,980	9,997
South Australia ...	7,161	6,881	7,725	7,279	7,213	7,169	2,517
Victoria ...	41	—	—	—	—	—	—
Western Australia...	2,094	636	1,266	559	686	570	111
Tasmania ...	4,730	7,815	7,920	6,338	5,894	5,593	5,027
Northern Territory	7	81	152	59	61	41	—
<b>TOTAL ...</b>	<b>46,493</b>	<b>38,426</b>	<b>39,978</b>	<b>38,807</b>	<b>39,429</b>	<b>38,358</b>	<b>19,183</b>

\* Metal contents of the ores, concentrates, etc., produced.

*Refined Copper Produced in Australia, and Metal in Blister, Matte, Ores, etc., exported from Australia*

(Statistical Report of the Australian Metal Exchange, 1921)

Year	Quantity (long tons)			
	Electrolytic and Fire Refined Copper.	Copper in Blister and Matte Exported.	Copper in Ores and Concentrates Exported.	Total.
1913 ...	21,963	21,159	1,435	44,557
1914 ...	24,905	12,158	995	38,058
1915 ...	28,446	7,702	967	37,115
1916 ...	34,828	3,994	405	39,227
1917 ...	35,989	—	—	35,989
1918 ...	44,018	—	—	44,018
1919 ...	16,182	—	—	16,182

*Exports of Copper from Australia*

(Statistical Report of the Australian Metal Exchange, 1921)

Year	Quantity (long tons)		
	Refined Copper	Copper in Blister, Matte, Ore and Concentrates exported	Total
1913 ... ..	21,161	22,594	43,755
1914 ... ..	22,670	13,153	35,823
1915 ... ..	28,976	8,669	37,645
1916 ... ..	34,103	4,399	38,502
1917 ... ..	32,497	—	32,497
1918 ... ..	22,067	—	22,067
1919 ... ..	21,902	—	21,902

*Exports of Copper Ore from Papua*

(Annual Reports on Papua)

Year	Quantity (long tons)				
1912-13 ... ..	...	...	...	...	1,285
1913-14 ... ..	...	...	...	...	1,150
1914-15 ... ..	...	...	...	...	695
1915-16 ... ..	...	...	...	...	864
1916-17 ... ..	...	...	...	...	1,322
1917-18 ... ..	...	...	...	...	1,109
1918-19 ... ..	...	...	...	...	229

*Imports of Copper Ore into Australia**Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth of Australia. Annual)

From	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	—	39	—	—	—
Union of South Africa ... ..	—	—	—	—	10
Papua ... ..	702	771	1,438	458	871
New Zealand ... ..	—	—	6	—	—
Fiji ... ..	—	3	—	—	—
New Caledonia ... ..	—	—	5	15	55
TOTAL ... ..	702	813	1,449	473	936

*Imports of Copper, Plate and Sheet (Plain) into Australia*

*Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth  
of Australia. Annual)

From	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	744	743	557	11	180
Canada ... ..	—	—	—	—	7
Straits Settlements ... ..	—	1	—	—	—
New Zealand ... ..	—	—	1	1	—
<b>Total from British Possessions</b>	<b>744</b>	<b>744</b>	<b>558</b>	<b>12</b>	<b>187</b>
Belgium ... ..	38	—	—	—	—
Germany ... ..	18	—	—	—	—
United States ... ..	44	27	29	196	538
Japan ... ..	—	15	17	18	4
Java ... ..	—	5	2	4	—
Other Foreign Countries ...	—	1	—	—	—
<b>Total from Foreign Countries</b>	<b>100</b>	<b>48</b>	<b>48</b>	<b>218</b>	<b>542</b>
<b>TOTAL ...</b>	<b>844</b>	<b>792</b>	<b>606</b>	<b>230</b>	<b>729</b>

*Imports of Copper Pipes and Tubes (Plain) into Australia*

*Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth  
of Australia. Annual)

From	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	684	397	207	32	260
Canada ... ..	—	—	2	—	6
<b>Total from British Possessions</b>	<b>684</b>	<b>397</b>	<b>207</b>	<b>32</b>	<b>266</b>
Belgium ... ..	27	—	—	—	—
Germany ... ..	12	2	—	—	—
United States ... ..	4	19	39	76	66
Japan ... ..	—	4	23	4	34
Java ... ..	—	3	2	—	—
<b>Total from Foreign Countries</b>	<b>43</b>	<b>28</b>	<b>64</b>	<b>80</b>	<b>100</b>
<b>TOTAL ...</b>	<b>727</b>	<b>425</b>	<b>271</b>	<b>112</b>	<b>366</b>

*Imports of Copper—Bars, Rod (Plain), Angle, Tee and Strips  
into Australia*

*Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth  
of Australia. Annual)

From	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	255	220	252	58	28
Straits Settlements ... ..	1	—	—	—	—
New Zealand ... ..	—	1	—	—	—
Total from British Possessions	256	221	252	58	28
Belgium ... ..	2	—	—	—	—
United States ... ..	9	8	7	10	15
Japan ... ..	—	2	9	18	6
Total from Foreign Countries	11	10	16	28	21
TOTAL ...	267	231	268	86	49

*Imports of Copper Wire into Australia\**

*Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth  
of Australia. Annual)

From	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	1,153	1,258	480	25	24
Canada ... ..	—	—	—	36	25
Straits Settlements ... ..	—	2	1	—	—
New Zealand ... ..	—	—	1	5	—
Total from British Possessions	1,153	1,260	482	66	49
Belgium ... ..	69	—	—	—	—
Germany ... ..	7	—	—	—	—
United States ... ..	181	275	30	126	217
Japan ... ..	—	6	6	82	149
Total from Foreign Countries	257	281	36	208	366
TOTAL ...	1,410	1,541	518	274	415

\* Not including covered copper wire.



*Imports of Sulphate of Copper into Australia**Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth of Australia. Annual)

From	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	735	352	488	242	72
Straits Settlements ... ..	6	21	—	—	—
Total from British Possessions	741	373	488	242	72
United States ... ..	—	—	34	131	—
Japan ... ..	108	33	288	953	478
New Hebrides ... ..	—	4	2	3	—
Total from Foreign Countries	108	37	324	1,087	478
TOTAL ...	849	410	812	1,329	550

*Exports of Copper Ore from Australia (Domestic Produce)**Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth of Australia. Annual)

To	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	6,517	4,452	30	—	—
Belgium ... ..	562	—	—	—	—
TOTAL ...	7,079	4,452	30	—	—

*Exports of Copper Ingot and Matte from Australia (Domestic Produce)*

*Fiscal years ending June 30*

(Trade and Customs and Excise Revenue of the Commonwealth of Australia. Annual)

To	Quantity (long tons)				
	1915	1916	1917	1918	1919
United Kingdom ... ..	27,500	29,517	23,852	20,515	18,179
Egypt ... ..	—	—	—	1,407	605
India ... ..	1,798	2,432	2,768	5,136	2,577
New Zealand ... ..	142	122	4	13	8
Other British Possessions ...	467	120	—	—	10
<b>Total to British Possessions</b>	<b>29,907</b>	<b>32,191</b>	<b>26,624</b>	<b>27,071</b>	<b>21,379</b>
Belgium ... ..	1,651	—	—	—	—
France ... ..	821	1,420	222	—	—
Germany... ..	470	—	—	—	—
Italy ... ..	10	—	260	—	—
Russia ... ..	—	3,081	8,973	—	—
United States ... ..	600	200	10	—	—
China ... ..	—	—	—	—	23
Japan ... ..	—	—	—	—	100
<b>Total to Foreign Countries</b>	<b>3,552</b>	<b>4,701</b>	<b>9,465</b>	<b>—</b>	<b>123</b>
<b>TOTAL ...</b>	<b>33,459</b>	<b>36,892</b>	<b>36,089</b>	<b>27,071</b>	<b>21,502</b>

**New Zealand\***

Ores of copper are found in New Zealand in no fewer than 32 localities, but during the past 50 years attempts to work them have been unprofitable. The total recorded copper production at the end of 1918 amounted in value to only £19,378. Prior to the inauguration of systematic records there was a considerable production from the mines on Great Barrier and Kawau Islands, in the Hauraki Gulf, and on the Dun Mountain, near Nelson. Prospecting has been carried on near Kaeo, Whangaroa; at Maharahara, near Woodville; and at Mount Radiant, near Karamea; but hitherto no important deposits appear to have been found.

**FOREIGN COUNTRIES**

**Austria-Hungary**

The most important deposits of copper ore in Austria are the interbedded copper lodes of the Mitterberg, Bischofshofen district, near Salzburg, which consist of cupriferous siderite, and are from

\* New Zealand Official Year Book, 1919, p. 587.

3 to 10 feet in thickness. Analogous deposits have been developed on the Brand and Buchberg lodes, further south. The annual production of copper in this district is between 1,200 and 1,800 tons.

At Schmöllnitz, in Hungary, the ore is principally pyrite, but carries chalcopyrite in pockets, and bornite in thin layers. The ore occurs as a bedded formation, and contains from 0·5 to 2 per cent. of copper.

At Graslitz, in Bohemia, close to the Saxon frontier, the ore occurs in veins and impregnations and consists mostly of pyrrhotite, chalcopyrite, pyrite and arsenopyrite, containing from 1 to 1·3 per cent. of copper.

The Bohemian output amounted to about one per cent. of the total copper produced in Austria.

Mines have been worked for copper near Schwaz in the Tyrol. These deposits contain silver. The Caroline and Francis mines have been opened up in this neighbourhood. The Caroline bed is from 3½ to 13 feet in thickness and occurs in dolomite with a quartz-siderite gangue containing copper pyrites and argentiferous grey copper ore.

#### *Production of Copper in Austria-Hungary.*

(Frankfurter Metallbank und Metallurgische Gesellschaft)

Year						Quantity (long tons)
1913	..	...	...	...	...	4,000
1914	...	...	...	...	...	4,000
1915	...	...	...	..	...	6,300
1916	...	...	...	...	...	7,400
1917	...	...	...	...	...	4,400
1918	...	...	...	...	...	3,400
1919	...	...	...	...	...	1,000†

#### **Bulgaria†**

Numerous deposits of copper ore are found at Kara Tépé, near Bourgas on the Black Sea, filling small fractures from 8 to 16 inches wide in the andesites of the district. Chalcopyrite and pyrite occur in a quartz gangue, with galena and blende as accessory minerals. A deposit near Bourgas is reported to have been worked recently under German control.

Farther south, at Kainarja, the andesite is amygdaloidal, the vesicles containing quartz and native copper. The San Nicholas copper mine is in this district.

Prior to the war the only deposit from which ore was being recovered was the Plakalnitza mine at Elisseina in the Vratsa district, which has been developed to about 400 feet in depth. The ore carries lead and silver and from 5 to 7 per cent. of copper.

\* Metall u. Erz, December 8, 1919, Vol. XVI, p. 577.

† Produced in territories corresponding to former Austro-Hungarian Empire.

‡ Handbook No. 22. Hist. Section of the Foreign Office, 1920, pp. 99-100. Information supplied by the Dept. of Overseas Trade.

It was concentrated and smelted to matte, containing about 60 per cent. copper, which was sent abroad for further treatment. During the war the mine was actively exploited by the Germans and left by them in very poor condition.

### Finland\*

Cupriferous deposits have been extensively mined on the north-west border of Lake Orijavi, in the province of Abo.

At the Orijavi mine, situated about 18 miles from the coast of the Gulf of Finland, operations started in 1757 and were continued without a break for 118 years. In 1906 mining was resumed, and in 1911 the probable available ore was estimated at 175,000 tons, averaging 4 per cent. copper. Since then a considerable additional tonnage has been disclosed. The ore is complex, consisting of chalcopyrite with gold and silver values, pyrrhotite, zinc-blende, and a little galena. The footwall is granite and the hanging-wall diorite. Developments by the Finnish-American company now owning the property disclosed a poorer zone at 400 feet, but at 500 feet richer ore was found. A flotation plant has been erected for the treatment of the complex sulphides. No information is available as to the production of copper during the period under review.

At Pitkaranta, on the north shore of Lake Ladoga, several deposits of copper and tin ore occur in slates and granite. Of these deposits only one appears to have been worked, this being a bed of garnet-hornblende rock, dipping at from  $40^{\circ}$  to  $50^{\circ}$  in the granite, through which chalcopyrite and tin-stone are disseminated. This bed has been worked for more than 70 years, and has an average width of about 15 feet. Elsewhere, along its length, the bed is worked for tin ore only, this being found not only in the garnet-hornblende rock (a width of about  $3\frac{1}{2}$  feet against the hanging-wall), but also impregnating the foot-wall granite for a width of more than 3 feet. No information is available as to the production of copper in recent years.

A new copper mine has recently been opened up at Outukumpu, on Lake Ladoga, the ore from which is smelted at Imatra. It is stated that 12,600 tons of ore were produced in 1918, and that an ore-body had then been proved containing from 6 to 8 million tons of ore averaging 4 per cent. of copper and 27 per cent. of sulphur.†

### France

The chief copper mines worked in 1913 were Fosses (Savoie), Padern and Montgaillard d'Ariac (Aude), but the production of copper ore in France has practically ceased owing to exhaustion of the known deposits.

Occurrences of copper ore are known in Corsica at Vezzani and other localities. The Tema-Vezzani mine is reported to have produced a small amount of copper ore during 1918.

\* Eng. and Min. Journ., 15th April, 1911.

† Min. Sci. Press, 1920, Mar. 13, p. 375.

*French Production and Imports of Copper Ore*

Statistique de l'Industrie Minérale en France et en Algérie,  
1914-1918. (Le Commerce de la France, Annual)

Year	Production		Imports (long tons)
	Ore (long tons)	Copper content (long tons)	
1913 ... ..	513	31*	9,498
1914 ... ..	108	11	10,545
1915 ... ..	93	10	2,565
1916 ... ..	1,040	40	1,566
1917 ... ..	1,355	54	3,965
1918 ... ..	798	23	420
1919 ... ..	37	2*	1,078

\* Estimated.

*Production of Copper in France*

Year	Metal Quantity (long tons)			Matte Quantity (long tons)
1913 ... ..	...	...	11,776	—
1914 ... ..	...	...	9,891	45
1915 ... ..	...	...	836	104
1916 ... ..	...	...	1,230	122
1917 ... ..	...	...	984	3
1918 ... ..	...	...	443	569
1919 ... ..	...	...	859*	—

\* Including matte.

*Imports of Copper, Cement, Cast in Crude Lumps, Granulated,  
Ingots and Anodes into France*

(Le Commerce de la France, Annual)

From	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
United Kingdom	6,488	4,340	3,951	8,392	5,266	5,561	2,795
United States ...	69,094	61,841	102,221	137,805	165,440	125,122	48,200
Other Countries	17,753	11,079	4,028	4,434	15,144	15,717	5,033
TOTAL ...	93,335	77,260	110,200	150,631	185,850	146,400	56,028

*Imports of Copper and Copper Alloys into France*  
(Le Commerce de la France, Annual)

Year	Quantity (long tons)		
	Rolled or beaten in bars or plates	Wire of all sizes	Filings or scrap
1913 ... ..	1,202	2,389	17,656
1914 ... ..	1,073	1,370	8,880
1915 ... ..	4,396	2,587	6,916
1916 ... ..	19,598	7,108	14,235
1917 ... ..	59,285	7,953	12,565
1918 ... ..	12,773	1,859	2,770
1919 ... ..	4,886	2,510	3,526

*Exports of Copper and Copper Alloys from France*  
(Le Commerce de la France, Annual)

Year	Quantity (long tons)			
	Cement, cast in crude lumps, granulated, ingots, plates and anodes	Rolled or beaten in bars or plates	Wire of all sizes	Filings or scrap
1913 ... ..	4,331	10,209	14,442	2,673
1914 ... ..	2,472	6,717	9,060	1,785
1915 ... ..	1,557	1,469	1,567	1,730
1916 ... ..	2,629	3,253	990	1,128
1917 ... ..	1,499	3,087	1,999	152
1918 ... ..	1,285	2,126	1,270	570
1919 ... ..	2,397	3,046	2,452	808

**Germany\***

For statistical purposes the German Empire is divided into two areas : the Rhine and the remainder of Germany. In the Rhine area about 57,000 tons of copper ore were mined in 1913, containing about 1,000 tons of copper. In the other districts some 890,000 tons of copper ore were mined in 1913, containing 25,619 tons of copper. In the Rhine area copper is usually associated with lead, and is found in many parts of Rhenish Prussia; near Eupen, in the Mayen district, and in the Neuwied district it is found in limestone; at Wallerfangen and St. Barbara extensive beds of a clayey nature contain nodular copper ore; at Commern azurite occurs with nodular lead ores, which also contain chalcocite and cuprite. Outside of the Rhine area copper-mining has been extensively carried on at Mansfield, in Prussia; at Ramelsberg, in the Harz; at Kupferberg, in Silesia; Riechelsdorf,

\* Ore Deposits, by Beyschlag, Vogt and Krusch.

in Hesse; in the Thüringerwald; and at Berggiesshübel, Freiberg, and other parts of the Erzgebirge, in Saxony.

The Kupferschiefer of Mansfield, which lies conformably below the Permian, is undoubtedly the most important occurrence of copper ore in Central Europe, and is the best known example in the world of a bedded sedimentary copper deposit. It consists mainly of a bed of bituminous shale, about 10 inches thick, carrying about 3 per cent. of copper and 5 oz. of silver per ton. The ore consists of chalcopyrite, bornite and chalcocite, with some pyrite and zinc-blende. The Mansfield district has produced probably not less than two-thirds of a million tons of copper. The metal content of the ore is very regular and it has been calculated that the deposits contain about 25,000 tons of copper per square mile.

The pyrite deposit at Rammelsberg, near Goslar, has been worked since the year 972. It lies beneath a tilted anticline of sandstones and slates, and occurs in a crushed zone, pitching at a high angle and resting on the broken edges of another series of slates which lie horizontally. The deposit is in two distinct bodies called "old" and "new" beds, but they both formed part of one body originally. At the Julius-Fortunatus adit the old bed is about 65 feet in thickness, while the new bed averages about 50 feet in its central portion. Both beds are lenticular in horizontal section. In some places the deposit is distinctly banded, a section from hanging-wall to footwall showing pyrite, copper ore, pyrite, pyritic lead ore, mixed ore and lead ore.

The different varieties of ore are approximately: Copper ore, containing 18 per cent. copper; copper ore, containing 10 per cent. copper; pyrite, containing  $2\frac{1}{2}$  per cent. copper; and mixed ore, containing  $4\frac{1}{2}$  per cent. copper,  $13\frac{1}{2}$  per cent. iron,  $20\frac{1}{4}$  per cent. zinc,  $10\frac{1}{2}$  per cent. lead, and  $24\frac{1}{2}$  per cent. sulphur. Grey copper ore also occurs, containing approximately 15 per cent. of copper and 55 per cent. of barytes. The deposit has been worked to a depth of about 1,200 feet, and the annual production before the war amounted to about 22,500 tons of ore of the different grades enumerated above.

The Freiberg area contains an entirely different class of copper deposit. Domes of grey gneiss and red gneiss, penetrating sedimentaries consisting of beds of limestone, greywacke, conglomerate and quartzite are intersected by two main groups of fissures of different age, of which more than 1,000 are known.

The older group contains lodes of pyrite, marcasite, galena, zinc-blende, arsenopyrite and chalcopyrite in a quartz gangue, and also lodes of pyrite, chalcopyrite, chalcocite and bornite. The younger group includes barytes-lead-silver lodes, with some copper ore in the form of chalcopyrite and bournonite. The zinc-lead-copper deposits occur principally at Halbrücke, Berthelsdorf, Brand and Erbesdorf.

A considerable quantity of copper has been obtained in the past from Freiberg and other parts of Saxony.

*Production of Copper Ore in Germany*

Zeits. f. d. Berg- Hütten- u. Salinenwesen, 1920, vol. 68, p. 18.

Year	Bavaria		Prussia	
	Copper ore (long tons)	Estimated copper content (long tons)	Copper ore (long tons)	Estimated copper content (long tons)
1913 ... ..	—	—	926,272	25,935
1914 ... ..	—	—	871,712	24,408
1915 ... ..	—	—	1,008,418	28,236
1916 ... ..	138	4	1,260,400	35,291
1917 ... ..	6,261	175	1,126,839	31,551
1918 ... ..	6,803	190	987,913	27,662
1919 ... ..	2,514	70	605,911	16,966

*Production of Copper in Germany\**

(Frankfurter Metallbank und Metallurgische Gesellschaft)

Year	Quantity (long tons)				
1913 ... ..	...	...	...	...	48,700
1914 ... ..	...	...	...	...	45,400
1915 ... ..	...	...	...	...	58,000
1916 ... ..	...	...	...	...	78,500
1917 ... ..	...	...	...	...	73,000
1918 ... ..	...	...	...	...	72,000
1919 ... ..	...	...	...	...	15,500

**Greece**

A small deposit of copper ore was formerly worked in the neighbourhood of the village of Dimaina, Morea, 7 miles from the town of Epidaurus. The ore in this neighbourhood is copper-pyrites, associated with serpentine.

The production of Greece is very small, the maximum recorded during the period being in 1914, when 82 tons of ore, containing 5 tons of copper, were produced.

**Italy**

In Liguria and Tuscany, iron-pyrites and copper-pyrites, associated with a little blende and galena, are found as bunches and strings or finely disseminated in basic igneous rocks.

The ore of the Libiola mine, north of Sestri Levante, near Genoa, contains from 4 to 9 per cent. of copper.

\* Crude copper from ores and intermediate products.



At Monte Catini, in Tuscany, about 6 miles west of the village of Volterra, copper ores are found as veins in gabbro. These veins contain chalcocite, bornite, native copper and a little chalcopyrite.

Some of the most important copper mines of Italy are situated at Boccheggiano, Capanne Vecchie, la Fenice, Serrabottini, and Monteccolino, in Tuscany, and are of an entirely different type from those of Monte Catini, being quartz veins carrying cupreous pyrites and chalcopyrite with bismuth and a little tin. At Montieri, grey copper is associated with fluorite.

At Boccheggiano a vein from 13 to 20 feet in width has been opened up for about 3,600 feet along its strike, containing lenticular bodies of cupreous pyrites and chalcopyrite in a quartz gangue. Only the richer portions, carrying 2.5 to 3 per cent. of copper, are worked. The annual production of the mine prior to 1913 was about 33,000 tons of ore, containing about 3 per cent. of copper.

At Agordo, in the Province of Belluno, in the district of Vicenza, an important deposit of cupreous pyrites has been developed. The workings date back to 1850, but were closed down for some time previous to 1912 when operations were resumed. The deposit, which is lenticular, has been proved for a length of 1,800 feet, a depth of 650 feet, and a width of from 13 to 260 feet. The mineralization consists of a fine mixture of pyrite and a little quartz with definitely banded chalcopyrite. The ore varies in content from  $\frac{1}{2}$  to 30 per cent. of copper, but the entire output has probably averaged about  $1\frac{1}{2}$  per cent. of copper. Galena, blende, argentiferous tetrahedrite, linnæite, and some arsenopyrite are present as accessory minerals. The district produced 14,406 tons of cupreous pyrites in 1917, this containing 42 per cent. of sulphur and 1.5 per cent. of copper.

*Production of Copper Ore and Cupreous Iron-Pyrites in Italy*  
(Rivista del Servizio Minerario, Annual)

Year	Copper ore		Cupreous iron pyrites	
	Quantity (long tons)	Copper content (long tons)	Quantity (long tons)	Copper content (long tons)
1913 ... ..	88,049	2,544	24,851	373
1914 ... ..	85,556	2,473	—	—
1915 ... ..	73,273	2,117	40,944	614
1916 ... ..	87,053	2,550	19,517	293
1917 ... ..	85,446	2,606	14,406	216
1918 ... ..	80,979	2,470	—	—
1919 ... ..	16,411*	507†	13,738	206

\* Including production in occupied territory.

† Excluding content of 26 tons of concentrates produced in the occupied territory.

*Italian Production, Imports and Exports of Copper*

(Rivista del Servizio Minerario, Annual. Statistica del Commercio Speciale di Importazione e di Esportazione, Annual)

Year	Production		Imports †	Exports †
	Crude Copper	Cement Copper*		
	Quantity (long tons)	Quantity (long tons)	Quantity (long tons)	Quantity (long tons)
1913 ... ..	2,057	—	38,916	2,738
1914 ... ..	1,809	—	27,965	1,681
1915 ... ..	925	—	53,842	877
1916 ... ..	846	991	67,266	908
1917 ... ..	1,228	82	91,618	385
1918 ... ..	1,096	31	78,315	125
1919 ... ..	1,223	165	78,149	1,166

\* Excluding the quantity used in the manufacture of crude copper. The copper content in 1916 was 80 per cent., and in 1917, 1918 and 1919, 78 per cent.

† The Imports and Exports consist of "copper, brass and bronze in ingots," "rosettes" filings and old broken articles, bars, sheets and castings. During the years 1913 and 1914 the United States supplied 60 per cent. of the total imports, Germany about 14 per cent., and the United Kingdom about 6 per cent. From 1915 to 1918 the United States supplied about 90 per cent.

**Jugoslavia\***

The copper mines of Maidanpek and Bor, in north-eastern Serbia, 72 and 84 miles respectively south-east of Belgrade, have been worked since Roman times, and have produced important quantities of copper. Before the war these two localities had a total production of about 7,000 tons of metallic copper per annum.

Copper ore has also been mined in north-west Serbia, notably at Rebelj and Wis, near Valjevo; in eastern Bosnia at Srebrenitsa; in central Bosnia in the neighbourhood of Fojnitsa and Kresevo; in Croatia at Breslinats, 48 miles south of Zagreb, and at Samobor, 13 miles west of Zagreb; and in Macedonia near Kratovo, and at Novo Brdo, 12 miles east of Prishtina.

The Maidanpek mines are on a zone of highly complex ancient rocks, much altered and intersected by more recent intrusions. This zone is approximately  $2\frac{1}{2}$  miles long by 650 yards wide. The ore occurs in large pyritic masses or as impregnations at the contact between limestone and andesite or in altered andesite. Chalcopyrite is the chief copper mineral, associated with pyrite, bornite, covellite, chalcocite and small quantities of zinc-blende and galena in a quartz gangue. The superficial deposits have been worked opencast and contain azurite, malachite, limonite, etc. Secondary enrichment has taken place in many cases. The ores usually range from 2 to 8 per cent. copper. Where pyrite occurs massive it is shipped for sulphuric acid manufacture. The

\* The Geology and Mineral Resources of the Serb-Croat-Slovene State, by D. A. Wray; Dept. of Overseas Trade: London, 1921.

copper ore is smelted on the spot. An aerial ropeway has been installed, 11 miles long, to Milanovats on the Danube. The concession belongs to a Belgian company, but during the enemy occupation was worked by the Austro-Hungarian Government, which daily sent 30 tons of copper ore to be smelted in Austria, in addition to large quantities of limonite.

The Bor mines are connected by a good road with the railway at Zayèchar, 17 miles to the south-east, and are owned by a French company. Many important deposits of copper ore occur as lenses between altered and unaltered andesites or in altered andesites, the largest being at Chuka Dulkan. At these workings a mass of ore, averaging 7 per cent. copper, has been developed for about 820 feet in length, 330 feet in depth and 85 feet in width. The mass is estimated at not less than two million cubic yards. The ore consists of cupreous pyrites with some chalcocite, covellite, bornite and enargite. Small values in gold and silver are also present and zinc-blende and galena occur sporadically. It is smelted and converted at the mines. Before the war about 3,000 men were employed, and the maximum output was 7,453 tons of metallic copper in 1911-12. During the enemy occupation very largely increased output was obtained, estimated at 30,000 tons of metallic copper in 1917.

Numerous similar occurrences of copper ore are found in the same district, notably at Zlot, Brestovats, Metovnitsa, Gamsigrad and Slatina.

### Norway

The Norwegian deposits of copper ore are usually low in copper values, and vary considerably. Since 1860 about 4 million tons of pyrite with a net content of about 96,000 tons of copper are said to have been exported. The principal deposits are found in the north of Norway, at Sulitjelma, Birtavarre; farther south, at Røros and Foldal, in the Trondhjem district; at Kopparstrand, near Kongsberg, and still farther south at Viksnes. All occur in the neighbourhood of plutonic rocks which are of the same geological type, often of a laccolitic character, and in areas of regional metamorphism.

The Norwegian ores may be divided into various types, but these all grade into one another. One type consists principally of pyrite, usually with some chalcopyrite and zinc-blende, the concentrates containing from 44 to 46 per cent. sulphur with from  $1\frac{1}{2}$  to  $3\frac{1}{2}$  per cent. of copper. Other types consist of pyrite and chalcopyrite, or pyrrhotite with chalcopyrite, and the smelting ore of these types contains from 4 to 6 per cent. of copper, and from 0.1 to 0.2 per cent. of nickel and cobalt. The ores have usually a banded structure, and in the flat bedded deposits, in which no secondary enrichment seems to have taken place, the copper-content appears to be very uniform.

The Sulitjelma mine, in Nordland, is the largest copper-producer in Norway, and one of the most important copper mines in Europe. The ore consists of cupreous iron-pyrites and pyrrhotite disseminated through mica-schist, or, massive in long,

narrow lenses at the contact between schist, amphibolite and olivine-gabbro. The ore is sorted by hand and then concentrated. The first product contains about 3 per cent. copper and 45 per cent. sulphur, and is shipped to acid makers; the richer ore is smelted at the mines and contains from 4 to 8 per cent. copper and from 32 to 34 per cent. sulphur. The concentrating ore, averaging about  $1\frac{1}{2}$  per cent. copper and 22 per cent. sulphur, is concentrated by gravity methods and by a flotation process. The average ore mined contains 2.45 per cent. copper and 45 per cent. sulphur. The concentration plant has a capacity of 1,600 tons per day, and the flotation plant is capable of producing about 25,000 tons per annum of concentrates containing 6.75 per cent. copper. The final product from the smelter is blister-copper, assaying about 99 per cent., which is sent to Helsingborg, in Sweden, to be refined. In 1913, the production of Sulitjelma amounted to 1,385 tons of copper and 125,000 tons of shipping ore. In 1920, the mine was closed down on account of the large stocks in hand.

The mines at Røros, in Guldal, produced 556 tons of copper and 12,000 tons of shipping ore in 1913.

The Foldal mine is reported to have produced 38,579 tons, containing 1.85 per cent. of copper and 44.8 per cent. of sulphur, in 1913.

At Viksnes, the deposit lies in a zone of schists and quartzites, much dislocated by intrusions of gabbro. The ore, which consists of iron-pyrites with varying quantities of chalcopyrite and zinc-blende, has averaged from 3 to 4 per cent. of copper and from 43 to 45 per cent. of sulphur.

During the early part of the war practically all the copper produced in Norwegian smelting works was exported to Germany, directly or indirectly, only small quantities being consumed locally.\* In 1916, a change was brought about by an agreement between the British and Norwegian Governments in which it was stipulated that exports to the belligerent powers should only take place in exchange for manufactured articles containing an equal amount of copper, less a small percentage for waste. Fairly large quantities of Norwegian copper were afterwards shipped to the United Kingdom in exchange for facilities to import manufactured copper and brass, but by far the largest quantity was sent to Sweden and returned in the shape of manufactured articles, while exports to Germany were very small.

At the time of the Armistice, the price of Norwegian Bessemer copper was very high, but, early in 1919, owing to foreign competition, the Norwegian smelting works were unable to compete at the ruling price, and closed down. They have since produced very little.

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\* Report on Commerce and Industry of Norway to the end of 1919 prepared by the Commercial Secretary to H.M. Legation, Christiania, 1920, pp. 86-87.

*Production of Copper Ore and Cupreous Iron-Pyrites in Norway*  
(Norges Bergverksdrift, Annual)

Year	Copper ore		Cupreous iron-pyrites	
	Quantity (long tons)	Estimated copper content (long tons)	Quantity (long tons)	Estimated copper content (long tons)
1913 ... ..	69,218	3,277	434,199	10,855
1914 ... ..	57,020	2,954	408,218	10,205
1915 ... ..	55,195	2,913	505,085	12,627
1916 ... ..	28,209	1,629	290,607	7,265
1917 ... ..	38,666	1,889	323,411	8,085
1918 ... ..	49,230	2,421	333,403	8,335
1919 ... ..				

*Production of Copper in Norway*  
(Norges Bergverksdrift, Annual)

Year	Quantity (long tons)		
1913 ... ..	...	...	2,697
1914 ... ..	...	...	2,814
1915 ... ..	...	...	2,783
1916 ... ..	...	...	1,588
1917 ... ..	...	...	1,781
1918 ... ..	...	...	2,810
1919 ... ..	...	...	1,800*

\* Subject to revision.

*Exports of Copper Ore and Cupreous Iron-Pyrites from Norway*  
(Statistisk Aarbok for Kongeriket Norge, Annual)

Year	Copper ore (long tons)		Cupreous iron-pyrites (long tons)
1913 ... ..	...	73	419,032
1914 ... ..	...	—	354,439
1915 ... ..	...	431	459,258
1916 ... ..	...	2,140	249,290
1917 ... ..	...	796	209,487
1918 ... ..	...	713	236,904
1919 ... ..	...	17	116,682

**Portugal**

The principal copper-ore deposit being worked in Portugal is that of the San Domingo mine at Mertola, close to the Spanish border, belonging to Mason & Barry, Ltd. It is a massive pyritic ore-body, very similar to those at Rio Tinto, Tharsis and other

localities in the south of Spain, and occurring in the same mineralized belt of country. The local mineralized zone is estimated to be 200 feet wide, and 2,000 feet in length, carrying lenses of cupreous pyrites. The principal ore-body, which is almost vertical, is a huge mass about 1,300 feet in length and 200 feet in width. The ore is reported to contain less than 1 per cent. of copper and about 50 per cent. of sulphur, the principal value being rather in sulphur than in copper. The copper content appears to have decreased slowly, but steadily, with increasing depth. In 1916, 202,176 tons of ore were raised at this mine, 154,762 tons in 1917, 80,079 tons in 1918, and 60,522 tons in 1919, abnormal conditions due to the war having, doubtless, hampered operations. At the end of 1918 the ore-reserves were estimated at 7,500,000 tons.

*Production of Copper Ore and Cupreous Pyrites in Portugal\**

(Boletim de Minas, Annual)

Year	Ore Quantity (long tons)	Copper Content Quantity (long tons)
1913	538,746	5,387
1914	424,961	4,250
1915	323,138	3,231
1916	233,127	2,331
1917	184,762	1,848
1918	110,079	1,101
1919	90,522	905

**Russia (European)†**

The most important copper-producing region in Russia is the Ural Mountains, which are partly in Siberia, where copper-mining has been carried on since 1745. Another important region is Transcaucasia. For other Russian copper mines *see* **Siberia**.

Copper-mining has been carried on vigorously in Russia since 1905, after a long period of comparative inactivity, the revival being due, largely, to the introduction of British capital and modern methods. Before the war the industry was protected by a Government bounty of 33 per cent., as a result of which the copper production of the Russian Empire rose to about 24,700 tons in 1911. In 1913 it amounted to about 34,000 tons; but, owing to conditions arising from the war, the production has since fallen very considerably, amounting to about 10,000 tons in 1918.

\* The figures for ore-production from 1916 to 1919 have been supplied by Sir Charles Fielding. The figures for 1913 to 1915 include small quantities of cement copper.

† S. H. Ball and B. Low; Eng. Min. Journ., 1917, vol. 103, 406-417. W. H. Weed; The Copper Mines of the World, 1908, 107-112. The Mineral Industry (Annual). Official reports. For **Siberia**, *see* p. 169.

*Ural District.*—In 1913 the copper output of this region amounted to 17,000 tons, or 50·4 per cent. of the total output of the metal in the Russian Empire. The principal copper mines are situated in the Perm and Orenburg Governments, on the western side of the Ural Mountains, which is the most highly mineralized section of Russia. There are several large productive mines in this region, and many that are nearing exhaustion after long periods of productivity. Among the more important producing mines are those of the Kyshtim group, situated about 30 miles from Kyshtim, in the Soymanovsk valley, Government of Perm, Southern Urals. A railway 26 miles in length connects these mines with the Trans-Siberian main line at Kyshtim. The copper ore-bodies of the group are regarded as deposits of the Huelva type, occurring in large lenses, each containing on an average about 1,000,000 tons. Mine-development and diamond-drilling have indicated a length of ore-body aggregating 4,500 feet, averaging about 11 feet in width, and representing about 600,000 tons of ore for every 100 feet of vertical depth. The combined ore-reserves of the five principal mines, as at present developed, are estimated at 3 million tons, averaging 2·8 per cent. copper, with 2 dwts. of gold and 1 oz. of silver per ton. The mines are equipped for an output of 1,500 tons of ore per day, and with a smelter at Karabash and an electrolytic refinery at Kyshtim capable of producing 14,000 tons of fine copper per annum. The production of blister copper in 1913 and 1914 was as follows :—

Year	Production	Content		
	Blister Copper (long tons)	Copper (per cent.)	Gold (oz. per ton)	Silver (oz. per ton)
1913... ..	8,413	98·8	3·56	33·6
1914... ..	7,467	98·8	4·22	41·0

It was expected that by the present date the annual production would have reached 12,000 tons, but this estimate has not been realized, the production of blister copper since 1914 having been as follows :—1915, 8,138 tons; 1916, 6,392 tons; 1917, about 5,000 tons.

The operating company owns a sulphate of copper works, with an annual capacity of 4,000 tons, in addition to coal and iron mines, iron-smelting works, dynamite factory and acid works.

In 1914 the cost of producing copper was 4½d. per lb., and in 1915 nearly 5½d. per lb., this being about covered by the value of the precious metal content and the Russian import duty on copper. After the export of bullion from Russia was prohibited in 1915, a parting plant was constructed for the separation of the gold and silver.

Important copper-mining properties on the east side of the Urals include the Bogoslovsk, the third largest producer of copper in Russia. The deposits in this locality occur as lenticular ore-bodies of the contact-metamorphic type between limestones and diorite, and are associated with, or near to, deposits of iron ore in crystalline schists. The ores are chiefly chalcopyrite, with some pyrite and pyrrhotite, but in one mine chalcocite persists to a considerable depth. Gold and silver are both present in amounts varying up to about 1 dwt. and 1 oz. respectively per ton. The lenses often attain widths of from 20 to 50 feet. Four mines were producing copper on this property during the early years of the war, these lying within a belt four miles in length. In one of these mines, the Bogoslovsk, now nearly exhausted, two gently dipping beds are stated to have yielded more than 1,000,000 tons of ore, averaging  $5\frac{1}{2}$  per cent. copper. In the Vassilyevsky mine the lenses are irregular and of rather small size, but are stated to have yielded, practically without sorting, ore averaging 13 per cent. copper. The Frolovsky and Nikitinsky mines are on more or less vertical, irregular lenses of ore. A small amount of cupriferous magnetite from the iron ore deposits has also been mined. The property is equipped with a smelter capable of treating 700 tons of ore per day, with converters and an electrolytic refinery. About 65,000 tons of ore are stated to have been mined in 1914, yielding 4,200 tons of copper, at a cost of about  $4\frac{1}{2}$ d. per lb. In 1918, the ore-reserves of the Bogoslovsk Mining Company were reported to amount to 3,400,000 tons, averaging 3.6 per cent. copper, to a depth of 660 feet.

The Mednorudiansk mine, in the Nijhni Tagilsk district, was the most important producer of copper in Russia prior to 1906, and is stated to have produced more than 3 million tons of ore, averaging 2 per cent. copper, since its discovery in 1720. The ore-bodies lie at the contact of limestone and diorite, the mine being famous for its pockets of rich oxidized ores, mainly malachite, which pass in depth into pyrite and chalcopyrite. The mine appears to be nearing exhaustion, the production of copper having fallen to less than 1,500 tons per annum.

Another notable property in the Ural district is that held by the Sissert Company, Ltd., about 30 miles south of Ekaterinburg, and traversed by the Ekaterinburg-Cheliabinsk Railway. The principal mines at the present time are the Sysselsky, opened up in 1906, the Gumeshevsky, and the Degtiarsky, a promising mine at the development stage, already well explored by drilling. The Gumeshevsky ore-bodies are similar to those of Bogoslovsk. The work at this mine consists in the treatment of large dumps of cupriferous clay, consisting of decomposed cupriferous limestone, by leaching with sulphuric acid. The plant is capable of treating about 80,000 tons of this material per annum, with a recovery of about 240 tons of copper at a profit of about £6,000. In June, 1916, about 500,000 tons of this material remained to be



treated. In addition, the mine itself is stated to contain important quantities of siliceous ore, averaging from 2 to 3 per cent. copper. The Sysselsky ore-bodies are chloritic schists. It is estimated that this mine still contains 70,000 tons of ore, averaging about  $4\frac{1}{2}$  per cent. copper. The ore is smelted at the Gumeshevsky smelter, sulphuric acid being made from the leaner pyrite. The ore in the Degtiarsky complex lens system is closely similar to that of the Kyshtim deposits, and more than  $3\frac{1}{2}$  million tons of cupriferous pyrites, averaging 2.77 per cent. copper, are stated to have been proved by drilling. The copper production of the Sissert Company's mines amounted to 1,491 tons in 1912, 1,316 tons in 1913, and 973 tons in 1914. The Company's properties include coal and iron mines, iron works, gold-bearing quartz veins, and gold-platinum placers.

The Degtiarsky lens system extends into the neighbouring Revdinsk estate, where it is reported that a smelter is to be erected.

The Tanalyk mines are in the Orsk district, Government of Orenburg, Southern Urals. In this region siliceous veins of cupriferous pyrites, with important precious-metal contents, occur in schists. The principal mines are the Tuba, the Semeonovsky, and the Sebaeva (a later discovery, only partly prospected by drilling and not yet equipped). In 1917—since which year very little work has been possible—the combined ore-reserves of this company's developed mines were estimated as follows :—

—		Tons	Copper (per cent.)	Gold (oz. per ton)	Silver (oz. per ton)
Sulphide ore ...	...	570,000	2.63	0.08	1.4
Oxidized ore ...	...	157,000	0.4	1.35	6.7

Another productive property in the Ural district is the Verkh-Issetsk. On this, two copper mines have been worked. One of these, at Ekaterinburg, known as the Pyshminsko-Klyutchevskoy, is regarded as a contact metamorphic deposit. In 1912, this mine produced 1,740 tons of copper from ore stated to have averaged 10 per cent. copper. The other mine, known as the Kalatinsky, situated near Nevyansk, is of the Huelva type, averaging slightly more than 2 per cent. copper. Pyritic smelting is adopted at this mine.

All these properties are situated on the eastern slopes of the Ural Mountains. In the plains to the west there are numerous deposits of copper ore, but they are of little economic importance. The ore-bodies are usually thin and of low grade (2 to 3 per cent. copper), occurring as impregnations of certain beds of Permian red sandstone, or as small bunches and veinlets.

*Transcaucasia.*—In 1913 the copper production of this region amounted to 9,900 tons, representing about 29 per cent. of the total Russian output for that year. The copper producers in this

region include the Mis-Dag mine, near Kedabeg,  $26\frac{1}{2}$  miles from Dalliär station, on the Tiflis-Baku Railway. The deposits, of which 16 are known, occur as lenticular masses varying in length from 33 feet to 820 feet, in width from 16 feet to 165 feet, and in thickness from 6 feet to 165 feet, in altered quartzite and sandstone, especially near their contact. The ore consists of chalcopryrite, pyrite, pyrrhotite and zinc-blende, in a barytes gangue. The ore, which is sorted underground into two grades, one above and the other below 5 per cent. copper, contains only a small amount of gold and silver. In 1914, 14,400 tons of ore were mined, yielding 794 tons (or 5.5 per cent.) of copper, but the production has since fallen to about 100 tons of copper per annum. The smelting-ore is practically exhausted, and the low-grade ores are being leached on a moderate scale.

The Dzansul mine, situated in the Artvin district, Government of Kutais, about 45 miles from Batum, and belonging to the Caucasus Copper Company, Ltd., contains what is probably the largest single copper ore-body hitherto found in Russia. The ore in sight in October, 1912, was estimated at 3,600,000 tons, averaging about 3 per cent. copper. The ore-body is a lens, 1,000 feet in length by 328 feet in width and 164 feet in depth, consisting of pyrite, chalcopryrite, and a little bornite, in a quartz gangue. It is worked as an open-cut, the overburden, varying in thickness from 10 to 100 feet, being removed by hydraulicing. The mine is equipped with a wet-concentration plant with a capacity of 1,000 tons daily, and the product is smelted, converted and refined at the Company's works. The concentrates are highly siliceous and there are heavy losses of copper in slimes and tailings. In 1914, a 400-ton-per-day flotation plant was installed and is expected to solve the treatment problems. The copper production immediately before the war was as follows:—1911-12, 3,030 tons; 1912-13, 2,992 tons; 1913-14, 3,936 tons, the costs being about  $6\frac{1}{2}$ d. per lb. Little work has been done since then.

The Kvarzhkhana mine, also situated in the Artvin district, and about 40 miles from Batum, belonging to a German firm, is equipped with a smelting and converting plant capable of treating 200 tons of ore per day. The smelter was shut down in 1914. The ore-body is a lenticular deposit at the contact of slate and quartzite. The ore-reserves were estimated at about 500,000 tons, containing  $4\frac{1}{2}$  per cent. of copper in the form of cupreous pyrites, the precious metal content being valued at about 8s. per ton of ore.

The Allah-Verdi mines, situated about 50 miles south of Tiflis, near the railway to Kars, were worked more than 160 years ago, and are now held on lease by a French company, which started operations in 1888. The ore-reserves are estimated to have a further life of only about three years. The ore, chiefly chalcopryrite in a quartz gangue, occurs as lenses in quartz-andesite, one of the largest mined being 600 feet in length, 120 feet in breadth, and 36 feet in thickness, the copper content averaging  $3\frac{1}{2}$  per cent., with only a small amount of gold and silver per ton. The

smelter has a capacity of 150 tons of ore per day, the ore treated being stated to average 5 per cent. copper. The annual production of copper is stated to be about 3,500 tons, the costs amounting to about 5½d. per lb.

There are numerous other small copper-producing mines in the Caucasus.

It is impossible to state with accuracy the total production of copper in European Russia during the period under review. The following table shows the total production of European and Asiatic Russia :—

*Production of Copper in Russia*

(Frankfurter Metallbank und Metallurgische Gesellschaft)

Year					Quantity (long tons)
1913	...	...	...	...	33,700
1914	...	...	...	...	31,700
1915	...	...	...	...	25,500
1916	...	...	...	...	21,000
1917	...	...	...	...	13,300
1918	...	...	...	...	10,000
1919	...	...	...	...	

**Spain\***

Copper ores occur in many localities in Spain; but the principal production, at the present time, is from the provinces of Huelva, Cordoba and Seville. In addition, copper ore has been produced in small quantities during the period under review from the following provinces :—Almeria, Avila, Badajoz, Barcelona, Corunna, Granada, Leon, Madrid, Malaga, Murcia, Toledo and Zaragossa. From this it is evident that the distribution of copper in Spain is very wide. Nevertheless, the huge masses of cupreous pyrites in the province of Huelva account for 90 per cent. of the Spanish production of copper.

Many of the mines are of great antiquity, the famous Rio Tinto mine having been worked successively by the Phœnicians, the Carthaginians and the Romans, and dating back to at least 1240 B.C.

All the principal copper-producing mines are situated on a mineralized belt of country stretching east from Portugal, across the province of Huelva, and nearly as far as Seville, a distance of about 120 miles. This belt of igneous rocks, including highly acid porphyries and "diabases," is characterized by numerous parallel "diabase" intrusions into Lower Carboniferous slates, the ore-bodies usually occurring along the contact, but occasionally entirely enclosed by the igneous rocks. Some geologists consider them to have been formed by the intrusion of molten sulphides, segregated from an igneous magma, but others claim that they are replacement deposits.

\* Pyrite in the Huelva District, Spain, by Courtenay de Kalb; Min. Sci. Press, 1921, Jan. 22, Vol. 122, pp. 125-130. Estadística Minera. Mines Handbook, by W. H. Weed. Mining Mag., 1919, Vol. XX., p. 332.

The size of the deposits varies greatly, but the total tonnage of ore already developed is enormous, and the potential reserves are even greater. The ore already extracted from the belt was estimated, in 1908, at not less than 125 million tons. In 1920, the proved reserves, in the province of Huelva alone, were estimated by a Spanish engineer at over 230 million tons. At the same time stocks of ore on the leaching beds were stated to be at least 25 million tons.

The deposits are usually marked by an oxidized cap or gossan, out of which the copper has been completely leached. Below this a zone of secondary enrichment sometimes occurs in which the precious metals are concentrated in a very narrow band at the junction with the gossan. In some localities the gossan outcrop is not visible, a notable instance being the Torera mine, near Calañas, where only small manganese outcrops were visible at the surface and where subsequent development exposed a large body of pyritic ore below.

The ore occurs as massive iron-pyrites traversed by fracture planes, which are coated with sooty chalcocite and films of chalcopyrite. The physical form of occurrence probably accounts for the ease with which the copper can be leached out and for the unique method of treatment which has been developed for these ores. The amount of arsenic present varies considerably between the limits of 0.001 and 0.8 per cent., and in this respect the ores are not so pure as some of the Norwegian ores from similar deposits.

The zone of secondary enrichment varies in depth considerably in different mines, and in the upper zone ore containing as much as 45 per cent. copper may occur.

The methods of treatment are based on the facility with which the greater part of the copper minerals in some ores can be oxidized and dissolved out, leaving the iron-pyrites unaltered and available for shipment as sulphur ore. The ore mined is, accordingly, divided into three main classes :—(a) The rich ores from the zone of secondary enrichment, which are smelted direct ; (b) the intermediate copper ore, containing about 3 per cent. of copper and 48 per cent. of sulphur, which is shipped to acid makers, payment being made for both the copper and sulphur contents ; (c) the leaching or cementation ore, containing from  $\frac{1}{2}$  to 2 per cent. of copper, which is piled at the surface on prepared floors and subjected to periodical leaching as the oxidation of the copper minerals proceeds. The solutions emanating from the leaching beds pass over pig or scrap iron, where the copper is recovered in the form of copper precipitate, or cement copper, containing from 60 to 90 per cent. of copper. The ore remaining after all copper amenable to the above process has been extracted is shipped, either with or without preliminary concentration, and sold as (b).

The Rio Tinto mine is one of the great mines of the world and has had a most successful career. Three ore-channels are being worked, known as the South Lode, the Dionisio Lode

and the North Lode. The more important are the two first mentioned and of these the Dionisio is likely to produce the greater part of the output in the future. The largest ore-body is in the South Lode, being approximately 3,300 feet long, 500 feet wide and 1,000 feet in proved depth. The mine is worked open-cast as deep as possible mainly by means of steam shovels. The deepest working of this kind is down about 600 feet, below which a system of top slice stoping is employed, the spaces being filled by overburden sent down from above. The deepest shaft is down 1,300 feet on the Dionisio Lode. The ore produced is graded into three classes, viz. :—smelting ore, containing from 2 to 5 per cent. of copper; shipping ore, containing from 1 to  $3\frac{1}{2}$  per cent. copper and from 47 to 50 per cent. sulphur; and leaching ore, containing from  $\frac{1}{2}$  to 3 per cent. of copper. The pre-war output of all grades of ore was about 2 million tons per annum, but during the period under review the quantity was considerably reduced. In 1913, a total of 1,859,571 tons of ore was mined, containing an average of 2.19 per cent. of copper. Metallic copper produced at the mines amounted to 21,062 tons, in addition to the copper sent away in the pyrites exported. There is a complete smelter and converter equipment at the mine, the product being blister copper, containing about 98 per cent. of the metal. This, together with the copper precipitate obtained from the leach beds, is sent to the Company's works at Port Talbot, in South Wales, where refined metal is obtained by the fire process and a certain amount of silver recovered.

The Tharsis mine is situated about 25 miles west of Rio Tinto. It is owned by the Tharsis Sulphur and Copper Company, Limited, Glasgow, and has had a most profitable history. Owing to the decrease in copper values in depth the mine production was much reduced and the main supplies were drawn from the Calañas mine, some 10 miles farther east, also belonging to the Tharsis Company. These mines produced 322,000 tons of ore in 1913. Recently, the Tharsis mine has been prepared for a large output of sulphur ore, and is stated to be capable of producing one million tons of pyrites per annum. Cupreous pyrites is shipped principally to the United Kingdom, and, after treatment by acid makers for the sulphur content, is sent to the Company's works (at Glasgow, Cardiff and on the Tyne) for recovery of the copper and preparation of the residues for sale as iron ore. Some gold and silver are also recovered in addition to the copper. In 1918, 3,246 tons of fine copper were produced. The ore-reserves of both the Tharsis and Calañas mines amount to many million tons.

The Huelva Copper and Sulphur Mines, Ltd., owns the Cueva de la Mora and Monté Romero mines, which are situated between the Tharsis and Rio Tinto mines. On June 30th, 1920, the ore-reserves were reported to be 113,500 tons of ore. The production from 60,597 tons of ore was 1,649 tons of copper. The mine equipment includes a pyritic smelting plant in addition to the usual cementation works.

The United Alkali Company, Ltd., owns groups of mines at Zalamea la Real, including the Castillo del Buitron, Poderosa, Concepción, Santa Rosa and Tinto mines. In 1916, the production was 177,107 tons of cupreous pyrites and 983 tons of copper precipitate. The annual production of copper from all the above groups is about 1,700 tons.

The Esperanza Copper and Sulphur Company, Ltd., owns the Esperanza, Nueva Esperanza, Angostura and Forzosa mines at Zalamea la Real. The only copper recovered direct on the property is a small amount of precipitate obtained from the mine waters. In 1919, 33,996 tons of ore were shipped. The ore-reserves, in 1918, were estimated at 886,000 tons.

The property of the Cordoba Copper Company, Ltd., is about 10 miles north-east of Cordoba, in the Cerro Muriano. Numerous veins occur in mica-schist, diorite and quartzite, the width ranging from 12 to 14 feet and the proved length from 600 to 8,500 feet. The ores consist of chalcopyrite and pyrite in a quartz and calcite gangue. The ore is low grade, and the crude ore mined in 1916 contained only 2.18 per cent. of copper. In 1918, 46,369 tons of ore treated yielded 1,453 tons of blister copper, but in 1919, the production was only 284 tons of metal, and the property was disposed of and the plant broken up.

The Guadalmez mine, in the district of Montoro, Cordoba, produced 3,272 tons of ore containing 27 per cent. of copper in 1917. The ore consists of chalcopyrite and chalcocite with a little oxide of copper and native copper. It occurs in a contact deposit between limestone and granite.

Numerous other small productions of copper ore were recorded from other parts of Spain during the period under review, but the only ore which calls for mention is that from the lead mines of Murcia. In some years an appreciable amount of copper ore is obtained from these mines. In 1917, 723 tons were produced containing 5 per cent. of copper.

Near Santiago de Compostela, in the province of Coruña, an extensive deposit of low-grade chalcopyrite ore is reported.

*Production of Copper Ore and Cupreous Iron-Pyrites in Spain*  
(long tons)

(Estadística Minera de España, Annual)

Year	Copper Ore		Copper-pyrites		Ferro-Cupreous Pyrites	
	Production	Copper content	Production	Copper content	Production	Copper content
1913 ... ..					2,232,230*	47,300†
1914 ... ..	25,677	1,513	799	53	1,451,976	29,040
1915 ... ..	22,697	2,131	1,969	129	1,440,816	28,816
1916 ... ..	24,775	2,610	—	—	1,720,637	30,511
1917 ... ..	82,160	9,039	—	—	1,788,624	35,773
1918 ... ..	13,008	853	—	—	978,466	16,768
1919 ... ..	850,522	53,728	—	—	595,943	8,528

\* Including Copper ore and Copper-pyrites.

† Estimated.

*Production of Copper in Spain*  
(long tons)  
(Estadística Minera de España, Annual)

Year	Ore treated	Ingots	Blister	Cement and Precipitate	Wire	Total
1914	715,226	1,911	12,489	10,204	689	25,293
1915	902,954	1,738	18,752	12,175	1,476	34,141
1916	3,055,457*	1,734	17,226	11,916	1,476	32,352
1917	1,461,192	1,529	21,131	12,761	1,486	37,907
1918	1,737,615	1,430	18,311	23,064	1,574	44,379
1919	1,556,608†	350	10,052	10,775	1,866	23,043

\* Excluding ore yielding 864 tons of copper precipitate which was produced in Sevilla.

† Excluding ore yielding 794 tons of copper precipitate which was produced in Sevilla.

*Exports of Copper from Spain*  
(Estadística General de Comercio Exterior de España, Annual)

Year	Copper Ore	Copper Matte	Copper Precipitate	Copper Bars
	Quantity (long tons)	Quantity (long tons)	Quantity (long tons)	Quantity (long tons)
1913 ... ..	157,807	211	5,777	23,240
1914 ... ..	80,977	—	9,894	14,691
1915 ... ..	29,046	—	10,275	15,800
1916 ... ..	44,874	—	11,248	14,432
1917 ... ..	30,824	—	11,574	18,646
1918 ... ..	21,991	—	9,698	10,726
1919 ... ..	216,483	30	10,086	4,056

**Sweden\***

Sweden possesses several important copper deposits, notably those of Falun, Ätvidaberg and Biersbo.

The deposits at Falun, in the province of Dalarne, are remarkable for their antiquity and continuous operation since the twelfth century. They occur in an area about 200 feet long and 1,300 feet wide, as irregular masses bounded by crush planes, and largely enclosed in crushed country rock, grey quartzite and granulitic gneiss. The largest of them pinches out at a depth of about 1,150 feet. The older rocks have been much folded and

\* Ore Deposits, by Beyschlag, Vogt and Krusch (Trans. S. J. Truscott). Mines Handbook, 1920, Weed. Gîtes Minéraux et Métallifères, De Launay.

disturbed. Dykes of felsite and trap cross the ore deposits, and other eruptives consisting of diorite and gabbro-diorite are found in the neighbourhood. The ore-bodies appear to be impregnation deposits, but their mode of origin is not at all certain. The ore appears to have averaged in recent years about  $3\frac{1}{2}$  per cent. of copper, but some of the hard ore contains as much as 6 per cent. and consists of grey quartzite, more or less impregnated with cupriferous pyrite and a little magnetite. The larger ore-bodies of soft pyrite carry from 2 to 3 per cent. of copper with a little gold and silver; but rich gold-ore intimately associated with seleniferous galena-bismuthinite and containing from  $3\frac{1}{4}$  to  $9\frac{1}{2}$  oz. of gold per ton was sorted out from veinlets traversing the hard ore. The total production from this mine is stated to have been 500,000 tons of copper, 15 tons of silver and  $1\frac{1}{2}$  ton of gold, the whole valued at 57 million sterling.

The copper deposits at Ätvidaberg-Bersbo, in Östergötland, south-eastern Sweden, have been extensively worked, and consist of cupriferous pyrite, magnetite and chalcopyrite associated with a little blende. At Ätvidaberg the mineral bed is from 1 to 10 feet in width, and lies between mica-schist and tourmaline-gneiss. At Bersbo the ore is associated with garnet, and other silicates, in fine grained gneiss, which is penetrated by granite intrusions.

The Stora Strand and Vingnäs mines, about 90 miles north of Gothenburg, are situated on a slate belt. The ore-body at the Stora Strand mine is reported to have been proved for several miles in length and for 800 feet in depth. The ore, which carries some silver and gold, is stated to average about 2 per cent. of copper.

*Production of Copper Ore and Cupreous Iron-Pyrites in Sweden.*

(Bergshantering Berättelse av Kommerskollegium, Annual)

Year	Copper Ore		Cupreous Iron-pyrites.	
	Quantity (long tons)	Copper content* (long tons)	Quantity (long tons)	Copper content† (long tons)
1913 ... ..	5,370	313	33,767	844
1914 ... ..	8,697	486	32,778	820
1915 ... ..	10,379	658	75,097	1,877
1916 ... ..	13,672	746	96,275	2,407
1917 ... ..	13,361	753	140,078	3,502
1918 ... ..	21,064	1,148	138,912	3,473
1919 ... ..	7,162	492	107,022	2,676

\* Ranges between about 2 per cent. up to 20 per cent. Average content over whole period 5·8 per cent.

† Copper content taken as 2·5 per cent.



*Swedish Production, Imports and Exports of Copper (long tons)*  
 (Bergshantering Berättelse av Kommerskollegium, Annual.  
 Handel Berättelse av Kommerskollegium, Annual)

Year	Production	Imports	Exports
1913 ... ..	6,780	9,034	1,266
1914 ... ..	4,617	11,851	3,978
1915 ... ..	4,488	13,014	2,215
1916 ... ..	3,130	10,894	1,509
1917 ... ..	4,352	3,655	150
1918 ... ..	2,908	3,986	32
1919 ... ..	3,501	14,487	527

*Swedish Imports and Exports of Copper Ore and Pyrites*  
 (Handel Berättelse av Kommerskollegium, Annual)

Year	Copper Ore		Pyrites	
	Imports (long tons)	Exports (long tons)	Imports (long tons)	Exports (long tons)
1913	10	1,682	138,739	492
1914	—	1,330	147,960	3,389
1915	—	3,292	156,654	39,355
1916	761	2,241	125,948	13,778
1917	546	—	102,224	29,321
1918	705	—	107,824	37,976
1919	116	—	70,559	—

**Switzerland\***

Copper ore has been mined at several places in Switzerland. In the Val d'Anniviers, mines have been opened up at Baicolliou, 1 mile south of Grimentz, and at Biolec and Pétolliou in the same district. The deposits are found in mica-schists and appear to be pockety and of low grade; the ore (copper-pyrites) is associated with bismuth, antimony and arsenic minerals. Concentrates obtained at the Baicolliou mine are reported to have contained about 18 per cent. copper, 2½ per cent. bismuth and 9 oz. of silver per ton. The mine has, however, been closed since 1914.

The Mürtschenalp mine is in a side valley of the Murgtal, canton of Glaris. The veins vary greatly in width. The richest ore is generally found in dolomite, and consists of bornite and chalcocite. This mine was once extensively worked, and was re-opened in August, 1916. Operations ceased in the autumn of 1918.

\* Der Schweizerische Bergbau, by H. Fehlmann, 1919, p. 255.

There are old copper mines near Andest in Val Schmuer. These contain copper-lead-zinc ores interbedded with quartz-porphry conglomerate, and associated with a quartz-porphry eruptive. The copper-pyrites, galena and blende are finely disseminated in the quartz. Work on these deposits was resumed in December, 1916, but does not appear to have given encouraging results.

### Algeria\*

There are numerous occurrences of copper ore associated with lead ore in Algeria, Morocco and Tunis. In Algeria many copper deposits consist of a mixture of complex sulphides in irregular veins, which occur in Mesozoic and Tertiary rocks in the neighbourhood of eruptive intrusions. Some are quartz veins, carrying both copper and lead, such as those of Bougie and Bône; others, between Tenez and Algiers, at Tadergount and elsewhere, contain chalcopyrite and grey copper-ore associated with galena, iron-pyrites, siderite and hæmatite; and at Cavallo, south-west of Jidjelli, galena and blende are found in association with copper and iron-pyrites. Most of these deposits, however, seem to be of an irregular nature, and seldom carry much high-grade ore.

A vein-deposit at Kef Oum Teboul, near the port of La Calle, consisted of an intimate mixture of pyrite, copper-pyrites, blende and argentiferous galena, in a gangue of quartz with a little barytes and fluorite. The copper ore extracted was divided into 3 classes:—No. 1, carrying 14 per cent. of copper and 29 oz. of silver per ton; No. 2, carrying 4 per cent. of copper and 47½ oz. of silver per ton, and No. 3, carrying 2.45 per cent. of copper and 12¾ oz. of silver per ton. In 1888, 14,400 tons of concentrates, consisting of copper ore and argentiferous galena, valued at £13,500, were shipped to Antwerp and Swansea, but in 1911 the production was only 1,519 tons of ore worth £2,044.

#### *Production of Copper Ore in Algeria.*

(Statistique de l'Industrie Minérale en France et en Algérie, 1914–1918)

Year					Quantity (long tons)
1914	...	...	...	...	182
1915	...	...	...	...	—
1916	...	...	...	...	121
1917	...	...	...	...	2,636
1918	...	...	...	...	1,756
1919	...	...	...	...	403

### Belgian Congo†

The Katanga region appears to contain the most important copper deposits yet discovered in Africa. Most of the Katanga

\* Diplomatic and Consular Reports. Trade of Algeria for the year 1912, p. 15. Statistique de l'Industrie Minérale en France et en Algérie (1914–1918).

† Mines Handbook, 1920; Eng. Min. Journ., 1920, Oct. 23, pp. 804–810. Min. Sci. Press, 1919, Dec. 13, p. 868. Foreign Office Handbook, No. 99, p. 116. Rapport Annuel du Congo Belge. Report of the Royal Ontario Nickel Commission, 1917.

ores contain from 7 to 8 per cent. of copper, but there are large deposits containing 10 to 20 and some up to 30 per cent. or more of copper.

The Union Minière du Haut Katanga was formed to work the Tanganyika Concession, which is situated in a region of rounded hills and steep side valleys, 4,000 to 5,000 feet above sea-level.

The nature of the surface ore does not lend itself to gravity methods of concentration, but against this must be set the high grade of the ores. The ore deposits are usually interstratified beds, but sometimes they cut across the bedding planes at right angles. Usually they are laminated like the sediments, which consist of a series of sandstones, schists, conglomerates and limestone.

The principal ore-bodies are lenses which vary greatly in size, and occur as impregnation deposits in fault-planes, cross-fissures and stratification-planes of the schists and quartzites. The ores are mostly oxidized, malachite being most abundant with a little azurite and chrysocolla in a siliceous gangue. Melanconite also occurs mixed with manganese. A remarkable feature of these Congo deposits is that the copper carries quite an appreciable amount of cobalt, which is recovered in course of refining.

The malachite beds usually dip almost vertically and in consequence of their resistance to denudation form prominent little hills.

The principal mines, in order of production, are, Kambove, Likasi, Star of the Congo and Chituru, but the Luiswichi and Luusha mines, 30 miles north of the Star, have also been developed and supply ore to the Lubumbashi smelter. The Luusha mine produced, in 1913, 20,000 tons of ore of a friable nature, containing considerable quantities of cobalt and iron. Such ores are briquetted.

The Star of the Congo mine is situated about 40 miles from the frontier of Rhodesia, and is connected by rail with the Cape and Delagoa Bay. Rich ore has been developed for 2,000 feet or more in length, and 100 feet in width, in four parallel beds, opened up to a depth of 90 feet by twenty shafts and a main haulage adit.

At the Kambove mine, 100 miles north-west of the Star of the Congo, on the navigable Lualaba-Congo route from the west coast, the principal ore-body has been proved for about 3,000 feet in length, and from 240 to 400 feet in width, and is being worked open-cast. It is developed by shafts to a depth of 100 feet and by a haulage adit 1,500 feet in length, half through pay-ore. Most of the ore is highly siliceous and contains up to 15 per cent. of copper. The estimated ore-reserves are stated to be 3 million tons, containing 13.4 per cent. of copper, above the adit level and an equal quantity of "probable ore," 100 feet below.

In the west of the Concession, close to the rivers Lualaba and Dilkulwe, other extensive outcrops occur said to carry 6 to 8 per cent. copper, but this is too low-grade to be profitably worked at present. The Union Minière Company estimate 40 million tons of 8 per cent. ore, above water-level, in all their Katanga mines. The following table indicates the progress made in the three years 1912 to 1914 inclusive :—

—				1912	1913	1914
Furnace days worked	...	...		171	443	671
Charges per furnace day	...	} long tons		178	198	212
Total charge smelted	...			29,793	86,389	141,361
Total output...	...			2,469	7,291	10,548
				£ s. d.	£ s. d.	£ s. d.
Average cost of fuel per ton	...			9 13 6	5 17 6	4 9 6
" " flux "	...			15 6	9 2	8 11
" " copper "	...			47 12 0	30 18 6	29 12 8

The Kasanchi copper-deposits, belonging to a subsidiary of the Union Minière, lie at an elevation of 5,000 feet, 12 miles south of the Congo-Zambesi divide, which forms the boundary between Rhodesia and the Belgian Congo. These deposits consist of beds of sandstone, impregnated with copper, resting upon limestone and schist. The main bed (known as D Reef), which is opened up for 1,000 feet or more, is reported to average 8 to 10 feet in thickness, with 5 to 10 feet of sandstone, impregnated with malachite, on each wall. The ore, as mined, is stated to average 18·7 per cent. of copper with 2 dwt. of gold per ton. The depth of the oxidized zone has not yet been determined, but sulphide ores with bornite and chalcopyrite associated with pyrite are exposed in depth, the main shaft having reached a depth of 300 feet in 1918.

The equipment of the Union Minière at Lubumbashi, near Elizabethville, includes furnaces having a total daily capacity of 1,000 tons of ore, *i.e.*, 100 tons of copper. A concentration plant with a daily capacity of 4,000 tons of ore, a leaching plant capable of producing about 50,000 tons of copper per annum and a 60,000 h.p. hydro-electric plant are in course of erection. The sulphuric acid required will be either imported or made from pyritic ores. Coke is supplied from the Wankie coal mines, Rhodesia, 725 miles distant, and the Company has a battery of ovens capable of making 2,400 tons of coke monthly. Notwithstanding the war, the copper output of the Lubumbashi smelter rose steadily from 981 tons in 1911 to 22,634 tons in 1919. The ultimate output anticipated is 40,000 tons per annum. The average cost of producing copper, including rail charges, freights, insurance, etc., was reported at £41 11s. 3d. per ton in 1916 and £62 10s. 0d. in 1918. With the completion of the Benguela Railway the overland route will be materially shortened and the ocean route to London reduced fully 3,000 miles.

*Production of Blister Copper in the Belgian Congo*

(Rapport Annuel, Congo Belge.)

Year					Quantity (long tons)
1913	...	...	...	...	5,324
1914	...	...	...	...	10,172
1915	...	...	...	...	13,814
1916	...	...	...	...	21,809
1917	...	...	...	...	27,055
1918	...	...	...	...	19,913
1919	...	...	...	...	22,634

**French Equatorial Africa\***

Copper deposits have been worked south of the Niari, or Upper Kwilu, and on the right bank of the Jue (Djoué) between Brazzaville and the sea. Copper has been worked in this district by the natives, who employed it for currency purposes. In this part of Africa there is a large area, between Loudima and Brazzaville, consisting of horizontal beds of magnesian limestones, resting on schists west of Loudima, and covered unconformably in the Upper Niari by Karroo sandstones.

The ore, which consists of malachite, diopside and oxides of copper near the surface and of chalcocite below it, has only been found in the limestone. It has been worked at Mindouli, in a bed from 3 to 7 feet in thickness, containing 35 per cent. of manganese dioxide and 16 per cent. of copper oxide, which outcrops on the side of a hill, and is capped with red clay. Speaking generally those deposits bear a certain resemblance to those of Mednorudiansk in the Urals, and at depth may turn into a mixture of chalcopyrite, galena, iron-pyrites and blende. Active work has been retarded by the excessive cost of transport. The opening of the Belgian railway to Leopoldville has now reduced these charges, and the Compagnie Minière du Congo Français has constructed a light railway to Brazzaville for the transport of ore.

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\* Gîtes Minéraux, De Launay, Vol. II., p. 795. British Foreign Office Historical Handbook on French Equatorial Africa, p. 50. Statistique de l'Industrie Minière dans les Colonies Françaises.

*Production of Copper Ore in French Equatorial Africa*  
(Statistiques de l'Industrie Minière dans les Colonies Françaises)

Year	Copper Ore	Copper Content	
	Quantity (long tons)	Quantity (long tons)	Percentage.
1913 ... ..	1,255	502*	40*
1914 ... ..	1,441	639	40-45
1915 ... ..	610	244	40
1916 ... ..	647	291	45
1917 ... ..	184	75	40
1918 ... ..			
1919 ... ..			

\* Estimated.

**Portuguese East Africa\***

Copper ore has been worked at the Edmundian mine, near Umtali, in the Mozambique Company's territory. The ore was formerly sent to Rhodesia, but a new plant was being erected in 1919 in order to treat the ore on the mine. The production was expected to be about 80 tons of copper per month.

**Portuguese West Africa (Angola and Cabinda)†**

Between the port of Mossamedes and the Sierra de Chella, cupriferous quartz-tourmaline veins, containing disseminated copper and iron-pyrites, have been discovered. They are connected with pegmatite intrusions and show secondary enrichment at surface. In the interior of Lunda there must be a certain amount of copper ore, as the caravans bring down blocks of copper, curiously shaped like the letter X, said to be smelted by the natives of that region.

Cupriferous conglomerates containing malachite, azurite and chrysocolla, with a little galena and barytes have been found at Senze do Itombe intercalated between beds of fossiliferous sandstone. Malachite is found in the vicinity of Bembe, south of San Salvador do Congo. The discovery of similar deposits is also reported from lower down the Brije River, on which Bembe stands, and also on the Kuvo, about 25 miles from its mouth. The malachite is often in solid blocks and in flat irregular veins, sometimes over 2 feet thick. About the middle of last

\* British Admiralty Manual of Port. E. Africa. South and East Africa Year Book. Board of Trade Journ., 1919, July 3, p. 18.

† British Foreign Office Historical Handbook, No. 120, p. 69. Gîtes Minéraux, De Launay, Vol. 2, pp. 714 and 790.

century, during a period of 15 years, 200 to 300 tons annually used to be brought down to Ambriz for sale by natives of the interior, and an English company took up a concession in the Bembe Valley. A few years later a bed of copper ore was found at Kwio, in the Benguella district, about 9 miles south of Dombe Grande. About 1,000 tons of good ore are said to have been extracted from this bed and considerably more from another bed higher up the river Kopororo. Ore from the latter also carried silver, from traces up to 100 oz. per ton.

### Cuba\*

Copper ore is found in Cuba in the States of Pinar del Rio, Santa Clara and Oriente.

The El Cobre property, eight miles west of Santiago Bay, covers a mineralized zone, 200 feet in width, which has been traced for 6,500 feet and contains three parallel veins in a hill of rhyolite tuff, with limestone and diorite to the south. The ore occurs in pockets and shoots up to 80 feet in width, in a vein of breccia, lying in contact with a fault-plane. In the deeper workings the ore is chalcopyrite, associated with pyrite in a quartz gangue, but nearer the surface the chalcopyrite is frequently coated with covellite. The oxidized zone extends to a depth of 75 feet. The ores are stated to average 4 to 5 per cent. copper. The mine, equipped with crushing and oil flotation plants of 600 to 700 tons daily capacity, produced about 900 tons of copper per annum, but was closed down in January, 1919.

The Matahambre mine, near the port of Santa Lucia, in the State of Pinar del Rio, between December, 1913, and April, 1914, shipped over 8,000 tons of ore, averaging 18 per cent. copper and 1.5 oz. silver per ton. In 1914, nearly 2,700 tons of copper are said to have been shipped and over 11,000 tons of copper in 1918. The ore occurs as chalcopyrite in lenses in a series of fault-veins cutting slates and shales.

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\* Mines Handbook, 1918 and 1920, Weed.

*Exports of Copper from Cuba to the United States*

*Fiscal years ending June 30*

(Foreign Commerce and Navigation of the United States)

Year	Quantity (long tons)									
	Ore			Concentrates			Matte and Regulus			Total Copper metallic Copper
	Quantity	Copper content	Per cent.	Quantity	Copper content	Per cent.	Quantity	Copper content	Per cent.	
1913 ...	35,905	2,829	7.88	—	—	—	—	—	—	2,833
1914 ...	29,177	4,561	15.63	—	—	—	—	—	—	4,561
1915 ...	61,080	10,844	17.75	—	—	—	188	38	20.21	10,882
1916 ...	69,789	14,412	20.65	6,900	1,073	15.55	*103	46	44.66	15,531
1917 ...	86,824	19,359	22.30	8,000	1,152	14.40	*340	211	62.06	20,726
1918 ...	78,681	14,792	18.80	11,540	1,731	15.00	—	—	—	16,523
1919 ...	...	...	...	+65,001	+9,560	...	...	...	...	9,560

\* Includes coarse metal and copper precipitate.

+ Includes ore, matte and regulus.

NOTE.—The United States is the only country to which Cuba exports copper.



## Hayti and Santo Domingo\*

At the Bucaro mine, on the river Nigua, 27 miles west of San Domingo, copper ore occurs in limestone near a porphyry contact. The ore contains both gold and silver, the chief copper-minerals being chalcopyrite, bornite and chalcocite. In 1915-16, 843 tons of sorted ore were produced, averaging 12·4 per cent. of copper with 6s. 9d. value in gold and silver per ton. From January to July, 1917, 227 tons of ore were produced, containing 12·78 per cent. of copper, but the mine was subsequently closed down.

## Mexico

Mexico contains a large number of important producing copper deposits in addition to great undeveloped resources. Owing to the disturbed conditions which prevailed in the country during the whole period under review, and, in fact, up to the present time, there are no recent and comprehensive data available for reference.

The American Smelting and Refining Co. owns many properties and carries on important copper-smelting operations at the following plants :—

—	Situation	Furnaces	Capacity daily (tons)
The Aguascalientes Smelter ...	Aguascalientes	8	2,000
The Matehuala Smelter ...	Matehuala ...	3	600
The Velardena Smelter ...	Asarco... ..	3	750

The company owns or controls various copper properties in Chihuahua, Coahuila, Durango, Aguascalientes, Michoacan, San Luis Potosi and Zacatecas.

The Compañía Metalúrgica Mexicana owns or controls the silver-copper mines at Concepcion del Oro, in the State of Zacatecas. The San Luis Potosi smelter belonging to the same company treats about 1,000 tons daily of gold, silver and lead ores, and has a special copper department of 100 tons daily capacity, copper and gold being mainly recovered as by-products.

The Compañía Metalúrgica de Torreon owns a custom smelter in the State of Coahuila with two 250-ton copper blast furnaces and a converter plant of 30-ton daily capacity capable of producing 2,500 tons of blister copper annually.

*Aguascalientes.*—The Alta Palmira mine produced auriferous and argentiferous copper ore and the Refugio mine contains ores carrying up to 10 per cent. copper and 36 oz. of silver per ton, with small gold values.

\* Mines Handbook, 1920, Weed.

The La Fortuna mine at Tepezalá contains oxidized argentiferous copper ores of commercial grade.

*Lower California.*—The interbedded deposits of the Boleo mines are situated in three valleys, about 19 miles from the smelting works at the port of Santa Rosalia. The copper is found in three principal beds of tuff, of Tertiary age, slightly inclined, resting on conglomerate, and containing oxides and silicates of copper. The sediments are associated with trachyte. The copper occurs in combination with silver, lead, cobalt, manganese and other metals. The oxidized ore is chiefly melaconite mixed with manganese and iron oxides. The sulphides, below water level, are covellite and copper-glance. The upper bed averages 3 feet in thickness, and contains much cupric oxide, carbonates and silicates being rare. The middle bed, from 2 to 3 feet thick, is more siliceous and carries copper silicates. The bottom bed varies from a few inches up to 16 feet in thickness, averaging about 3 feet. The oxide and carbonate ores in the middle bed are in oolitic concretions, known locally as "boleos." The lowest bed carries sulphide ores, as well as oxides and carbonates, and has been the chief source of supply. The ore is disseminated through the tuff in thin irregular veins, with clay gouge, and forms concentrated compact layers 6 to 12 inches thick towards the bottom of each bed. The Boleo Company treats about 1,000 tons per day of ore, averaging from 4 to 5 per cent. copper, and has seven blast-furnaces in operation with a capacity of 200 tons each per day. The final product is blister copper, assaying 93 per cent., and matte containing 63 per cent. of metal. In 1913, 368,334 tons of ore were smelted, yielding 3.47 per cent. or 13,000 tons of copper. In 1914, 318,793 tons of ore smelted yielded 3.53 per cent., or 11,253 tons of copper, and in 1917, 254,247 tons of ore smelted yielded 3.57 per cent., or 9,077 tons of copper.

*Chihuahua.*—This State is best known as a silver producer, but it also contains copper deposits, amongst which may be mentioned the Rio Tinto Mexicana mines at Terrazas, which are on a metamorphic zone traceable for about 5,000 feet, containing contact deposits between limestone and altered andesites. There are five known ore-bodies, averaging about 20 feet in width, which are practically continuous. The ore also occurs between the bedding planes of the limestone near a large quartz lode. It is oxidized at the surface, passing into sulphides below. The oxidized ore averages 3 per cent. copper, 2 to 4 oz. of silver and from  $\frac{1}{4}$  to  $\frac{3}{4}$  dwt. of gold per ton. The production of the Rio Tinto Mexicana Company group for 1906-1910 was reported to be 4,085 tons of metal, costing  $6\frac{1}{2}d.$  per lb. of finished copper. The Company owns a smelting plant at Terrazas, comprising blast furnaces and a converter plant. The mine and smelter were operated in 1913 almost continuously, but have been closed down since, owing to the revolution in Mexico.

*Coahuila.*—The State of Coahuila possesses several copper mines.

The Santa Maria, Sultana and other mines at Jimulco carry auriferous and argentiferous copper and lead ores.

The Panuco mine contains a deposit in granite, in a chimney of breccia cemented together by sulphides, principally chalcopyrite with a little chalcocite in a quartz gangue. The ore is reported to average about  $3\frac{1}{2}$  per cent. copper.

*Guerrero.*—The only developed copper mines in this State that appear to be of any importance are the El Rey del Cobre group in La Union district, 28 miles north-east of Zihuatanejo, the nearest port. The main lode, in schist, is said to be traceable for 3 miles, carrying lenses of cupreous pyrites. The ore is estimated to average 1.5 per cent. copper, 48 per cent. sulphur, 42 per cent. iron, and 1s. 8d. in silver and gold per ton. The ore reserves at the end of 1915 were estimated at three million tons.

*Michoacan.*—The Inguaran group of mines, on Inguaran mountain in the Tacambaro district, are situated on the volcanic plateau of Jorullo. The mountain is traversed by a dyke of fine-grained pink granite 2,000 to 3,000 feet wide, with chalcocite and chalcopyrite disseminated through it, forming a so-called "porphyry deposit," in which the payable ore occurs in belts or bands. The ore reserves are estimated at about  $2\frac{1}{2}$  million tons, averaging  $3\frac{1}{4}$  per cent. copper.

*Oaxaca.*—The San Juan mine,  $2\frac{1}{2}$  miles north of San Martin, Ejutla, has been a steady producer since 1906. Four fissure veins traverse porphyry, and the ore, consisting of chalcopyrite in a quartz gangue, occurs in lenses. The reserves were estimated in March, 1912, at one million tons of ore, averaging from 4 to 5 per cent. of copper and 15 oz. silver per ton.

*Puebla.*—The Teziutlan mine, at La Aurora, had reserves, in 1912, amounting to 600,000 tons of ore, containing 2.4 per cent. copper, and 7s. 6d. in gold and silver per ton.

*San Luis Potosi.*—The Dolores mine, at Matehuala, owned by the American Smelting and Refining Company, is a contact deposit in limestone and porphyry. The ore-shoots are large for this type of deposit, and one of them is stated to be about 300 feet long, 6 feet wide, and 300 feet deep. The contact-rock is reported to average 3 per cent. of copper,  $1\frac{1}{2}$  dwt. of gold, and 2 oz. of silver per ton. The Matehuala smelter, owned by the same company, on the Mexican Central Railway, has a plant with a capacity of 400,000 tons of ore per annum, and produces a matte, averaging 45 per cent. copper and 42 per cent. sulphur, which is sent to Aguascalientes for conversion.

*Sonora.*—This State contains a number of very important copper deposits.

The property of the Democrata Cananea Sonora Copper Company lies between the Capote and Veta Grande mines of the

Greene Cananea Copper Company. The ore-body consists of a breccia of altered limestone cemented by quartz, bornite and copper-pyrites in a fracture zone 50 feet wide in limestone associated with diorite-porphry. Average assays are stated to be  $3\frac{1}{2}$  per cent. copper and  $1\frac{1}{2}$  oz. of silver per ton. The company owns a smelter and converter plant, and from November 1st, 1917, to December 31st, 1918, 6,795 tons of copper were produced, containing 8,877 oz. of silver and 334 oz. of gold.

The Greene Cananea Copper Company controls a most important group of properties in the same district, the principal mines being the Veta Grande, Oversight and Capote. They are situated in the Cananea mountains in northern Sonora, distributed along a series of mineral belts about 6 miles long and 2 miles wide. In this district the basal pre-Cambrian granite is overlain by Cambrian quartzite with Cambrian limestone resting upon it, the whole being penetrated by a series of Tertiary eruptives. The deposits are of three classes: (1) shear zones in diorite-porphry containing secondary chalcocite, with massive or disseminated pyrites; (2) contact deposits, containing chalcopyrite associated with iron-pyrites and some zinc-blende in a matrix of altered limestone; (3) diorite-porphry breccia, containing disseminated chalcopyrite associated with zinc-blende.

The Capote mine differs from the Veta Grande and Oversight in that the ore occurs not only disseminated through diorite-porphry in broad shear zones, but also in the underlying granite. The ore in the upper levels is chiefly chalcocite, but the "new shoot" consists of massive pyrite with primary chalcopyrite and bornite in granite. This mine has three principal ore shoots, and has been developed to a depth of over 1,050 feet. It yields both direct-smelting and concentrating ore. Other important mines belonging to this company are the Sierra de Cobre and Elisa. The production of the Greene Cananea group in 1913 amounted to 683,092 tons of ore, containing 2.36 per cent. of copper. The smelter production was 19,857 tons of copper, 1,497,938 oz. of silver, and 8,021 oz. of gold, at a cost of 4s. 8d. per lb. of copper. In 1918, 1,044,641 tons of ore were mined, containing 2.43 per cent. of copper, and the smelter production was 23,525 tons of copper, 1,666,993 oz. of silver, and 9,846 oz. of gold, at a cost of 7 $\frac{1}{2}$ d. per lb. of copper.

In the Hermosillo district, about 28 miles north-west of Hermosillo, the Picacho and Verde Grande mines are on contact deposits in limestone near igneous intrusives, the oxidized ore assaying up to 6 per cent. copper, 8 oz. silver and 1 dwt. of gold per ton. The Cobriza group and La Verde are on contact deposits between granite and quartzite, claimed to be from 30 to 60 feet in width and 7,000 feet in length, containing auriferous and argentiferous copper ore, assaying from  $5\frac{1}{2}$  to 20 per cent. of copper, in a gangue of talcose limestone. Seven ore-bodies are reported to be under development of from 10 to 100 feet in width, averaging 5.44 per cent. copper, 8.8 oz. silver and  $\frac{3}{4}$  dwt. of gold per ton. Ore proved is reported at 200,000 tons.

The Pilares de Nacozari mine, controlled by the Phelps Dodge Corporation, is situated in the Moctezuma and Arizpe districts, and lies in high and precipitous country near the divide of the Yaqui and Oposura rivers. The ore deposit is described as an oval-shaped, brecciated mass of andesite-trachyte having a major axis of 2,000 feet and a minor axis of 1,000 feet formed by two parallel systems of faults at right angles to one another. The andesite-trachyte gives place to andesite and this to monzonite in depth. The ore occurs mostly on the borders of the breccia but smaller bodies are formed within it also. The ore consists of chalcopyrite, with pyrite, bornite, chalcocite and covellite, and is mostly of concentrating grade. In 1918 the ore mined averaged about 3.4 per cent. copper. The ore reserves are reported at over three million tons. In 1913 the Pilares group of mines produced 16,338 tons of copper, and in 1918 ore containing 19,140 tons of copper, 11,103 oz. of gold, 923,922 oz. of silver and 7,024 lb. of molybdenum.

The Verde and Cobre Rico mines are situated 25 miles southwest of Cumpas. The Cobre Rico mine has been extensively opened up, developing several ore-bodies in the form of chimneys or pipes in a mass of brecciated rock, locally known as trachyte. It is reported that the ore averages 2 per cent. copper, from 1 to 2 oz. silver and a trace of gold per ton, and that two and a half million tons are available. In the Verde mine extensive drilling has developed a large tonnage of low-grade primary ore averaging 1½ per cent. copper, estimated at three million tons.

*Zacatecas.*—The Mazapil group of mines belonging to the Mazapil Copper Company, Coahuila, comprises the Aranzazu and Cabrestante, where copper ores, in irregular masses in limestone near granite-porphry contacts, have been extensively developed. The company also owns copper and silver-lead smelters at Concepcion del Oro and Saltillo, which produced 5,234 tons of copper in 1918.

### *Production of Copper in Mexico*

(Secretaria de Industria, Comercio y Trabajo, Departamento de Minas)

Year						Quantity (long tons)
1913	...	...	...	...	...	51,747
1914	...	...	...	...	...	26,193
1915	...	...	...	...	...	20,272
1916	...	...	...	...	...	27,954
1917	...	...	...	...	...	50,127
1918	...	...	...	...	...	69,072
1919	...	...	...	...	...	51,432

### United States\*

The production of copper in the United States is far greater than that of any other country, averaging about eight times that of the next largest producer during the period under review. In fact, the production of the United States in this period was greater than that of the whole of the rest of the world. Following the reaction caused by the outbreak of war in 1914, the production steadily increased to a maximum of 860,646 tons in 1916, which was an increase of no less than 57 per cent. over the figure for 1913. The high rate of production was maintained until the Armistice, but thereafter the decline was very rapid, being only 574,294 tons in 1919, or 27,650 tons more than in 1913. This decline resulted from the cessation of war demands, coupled with the enormous stocks on hand at the Armistice for which there was little demand. The general effect of this state of affairs was accentuated by the quantity of scrap metal made available from the sale of war dumps. Naturally, these conditions reacted on prices which, after a fall at the outbreak of war, steadily rose to a maximum of 37 cents per pound for electrolytic in March, 1917. In September of that year the War Industries Board fixed the price at 23½ cents per pound, and in July, 1918, at 26 cents per pound. Concurrent with the rise in selling price of the metal, there was a greater proportionate increase in cost of production, owing to increases in wages, higher cost of materials, and the lower efficiency of labour. This is well shown by the following table taken from the reports of some of the large producing mines:—

*Cost per pound in cents*

	1913	1916	1918
Utah ... ..	8·64	6·92	14·53
Chino ... ..	8·78	8·70	17·17
Ray ... ..	9·87	10·26	18·05
Nevada ... ..	9·99	8·67	17·98
Anaconda ... ..	9·0	9·50	15·00
Inspiration ... ..	not working	8·86	11·26
Calumet and Hecla ... ..	14·23	11·63	21·05
Miami ... ..	10·60	9·52	14·83

The control of prices was withdrawn at the close of 1918 and there was a steady fall from then onwards. In December, 1919, the average price for electrolytic copper was 18·48 cents per pound.

The principal producing States, in order of importance, are Arizona, Montana, Michigan, Utah, Nevada and New Mexico.

\* Mineral Resources of the United States.

Of these, Arizona is far ahead of the others owing to the number of important producing districts in that State. Of individual districts the most important is Butte, Montana, followed very closely by the Lake Superior district of Michigan, where copper mining on an important scale first began in 1845. Although occurrences of copper ore are widely distributed throughout the United States, the only important producing centres east of the Rocky Mountains have been those of Lake Superior, and Ducktown, Tennessee. The output elsewhere has not amounted to more than 5 per cent. of the total for the United States.

The copper ore deposits of present commercial importance may be classified according to age, but the most convenient classification is according to mode of occurrence. It is computed that the Palæozoic rocks have contributed only from  $1\frac{1}{2}$  to 2 per cent. of the total production, as against 32 per cent. for the pre-Cambrian,  $18\frac{1}{2}$  per cent. for the late Jurassic and early Cretaceous, and 46 per cent. for the Tertiary. The following table shows the classification of the chief deposits according to their occurrence, together with their probable age:—

Mode of occurrence	Percentage of total output		Examples	Probable age
	Up to 1913	In 1913		
Lenticular replacements in schistose and igneous rocks.	8.0	7.56	Jerome district, Arizona. Shasta county, California. Ducktown, Tennessee.	<div> <div>Pre-Cambrian.</div> <div>Mesozoic.</div> <div>Palæozoic</div> </div>
Native copper in volcanic and associated rocks.	28.4	12.72	Lake Superior, Michigan.	
Replacement deposits in sedimentary rocks.	20.6	24.0	Bisbee, Arizona (Copper Queen, Calumet and Arizona).	
Disseminated deposits	10	32.5	Morenci (part of) Copper river, Alaska (Kennecott-Bonanza).	<div>Mesozoic.</div> <div>Tertiary.</div> <div>Mesozoic.</div>
			Yerington, Nevada	Mesozoic.
			Bingham, Utah ...	Tertiary.
			Bingham, Utah (Utah Copper Co.)	Tertiary.
			Ely, Nevada ...	Mesozoic.
			Morenci, Arizona (Arizona Copper Co.)	Tertiary.
Fissure-vein deposits	33.1	23.2	Miami, Arizona ...	Mesozoic.
			Ray, Arizona ...	Tertiary.
			Butte, Montana ...	Tertiary.

The lenticular deposits usually contain, as primary minerals, sulphides of iron, copper and zinc replacing the enclosing schistose rocks, the structure of which may be the result of regional metamorphism or of local shearing. In many of these deposits there is an enriched upper part containing secondary sulphides. The ores are usually of low grade, but are easily mined and treated.

The native copper deposits of importance are all in the Lake Superior district, but similar deposits have been found in some of the eastern States and in Alaska. The native copper occurs in irregular ore-shoots in beds of volcanic material, or in volcanic material interbedded with sedimentary rocks. The ores are usually low grade but easily concentrated and smelted.

With the replacement deposits are included contact deposits and those formed by replacement of sedimentary rocks along planes of fracture. The rocks replaced are usually limestones or highly calcareous. The primary minerals are generally sulphides of copper and iron with other metallic sulphides. Alteration has been extensive in many cases, and some of the oxidized ores contain high values in copper. The ore is usually of smelting grade.

The disseminated ores are generally known as the "porphyries" on account of the fact that the copper minerals commonly occur in this kind of igneous rock. This is not, however, invariably the case. The primary minerals are pyrite and chalcopyrite, with other associated sulphides. Secondary enrichment has usually taken place, the secondary mineral, as a rule, being chalcocite. In some deposits of this type, native copper and cuprite are of importance. Other deposits of this type are worked only in the zone of primary ores. These deposits occur in igneous, schistose and sedimentary rocks, through which the ore minerals are found in small veins or grains. They are usually of low grade but of large extent, which permits them to be mined and concentrated at small cost. In recent years the production from this class of deposit has increased enormously.

The fissure-vein deposits are taken to include those formed in fissure veins and as replacements along such veins, and there is no sharp division between this type and that of the disseminated ores. The minerals are the same but the ore is mostly of high grade suitable for smelting. Secondary enrichment is common. At Butte, which is the great example of this type, enargite is a common and important constituent of the ores.

The quantities of ore in reserve in the principal districts are proportionate to the output of the country. It has been stated that the reserves of low-grade ore in Michigan are greater than anywhere else in the world. The Miami, Ely, Bingham and Ray fields are said to have a total of over 700 million tons of ore developed, apart from enormous probable reserves.

The principal copper-mining enterprises of the United States will be described under their respective States, but the following



table shows the most important, in 1918, with their respective productions in terms of refined copper :—

Name	State	Output, 1918 (long tons)
Anaconda Copper Mining Company ... ..	Montana	121,840
Utah Copper Company ... ..	Utah	83,970
Inspiration Consolidated Copper Company ... ..	Arizona	43,991
Copper Queen Mine (Phelps Dodge Corporation) ... ..	"	40,619
Ray Consolidated Mining Company ... ..	"	37,321
United Verde Copper Company ... ..	"	34,625
Nevada Consolidated Copper Company ... ..	Nevada	34,200
Chino Copper Company ... ..	New Mexico	33,775
Calumet and Hecla Mining Company ... ..	Michigan	30,343
Kennecott Copper Corporation ... ..	Alaska	27,230
Miami Copper Company ... ..	Arizona	26,075
United Verde Extension Mining Company ... ..	"	24,773
Calumet and Arizona Mining Company ... ..	"	22,727
Old Dominion and Globe (Phelps Dodge) ... ..	"	21,531
New Cornelia Copper Company ... ..	"	20,960
Arizona Copper Company ... ..	"	18,054

Although, in the above table, the Anaconda Company comes first, the Utah Copper Company would rank before it for magnitude of operations from a single deposit. Whereas, in 1918, the Anaconda Company obtained its output from 3,884,327 tons of ore from very numerous mines, the Utah Company's output was from 10,857,768 tons of ore mined from a single deposit.

In the following descriptions, only mines which have produced a quantity of copper ore equivalent to 2,500 tons of copper per annum are dealt with. The number of smaller producers is large. Productions are given for the year 1918, as, owing to the disorganization of the copper market since the Armistice, this is the last year in which the capabilities of the mines are indicated by their outputs.

*Alaska.*—The production of Alaska largely increased during the period under review. The principal mines are the Beatson, Bonanza and Jumbo, all belonging to the Kennecott Copper Corporation.

The Beatson mine is situated on Latouche Island, Prince William Sound. The ore consists of chalcopyrite, pyrite and other sulphides, occurring as a large lens in a brecciated slate shear zone. It is treated by the flotation process in a mill of 1,500 tons daily capacity, the tailings being leached with ammonia. The production in 1918 was 355,224 tons of ore, containing 2·02 per cent. copper, and the concentrates, shipped to smelters at Tacoma and Anyox, amounted to 44,567 tons, averaging 12·8 per cent. copper with some silver.

The Bonanza and Jumbo mines are situated near Kennecott, on a tributary of Copper River. The former contained a large mass of high-grade ore, up to 60 per cent. copper, but this is now largely worked out. The deposits consist of limestone replacements near a greenstone contact; the primary mineral consisting

of chalcocite with some bornite. This is one of the few deposits of importance in which chalcocite is regarded as a primary mineral. The ore is concentrated by ordinary gravity methods in a mill of 700 tons daily capacity, and an ammonia leaching plant of 600 tons daily capacity is also employed on treatment of tailings. The production from these mines reached a maximum of 45,272 tons of copper in 1916, the cost being 5.1 cents per pound of copper, but has since fallen considerably.

*Arizona.*—This is by far the most productive State for copper ores, a maximum output of 343,536 tons of copper being obtained in 1918. The principal districts are Bisbee, Globe-Miami, Morenci-Metcalf, Jerome, Ray, Pioneer and Silverbell. The production has grown very rapidly in recent years, the output in 1918 being more than 85 per cent. higher than in 1913.

In the Bisbee district, on a foundation of pre-Cambrian schists intruded by granite, there are very thick sedimentary beds, consisting of quartzite and limestone. These beds, in turn, were intruded by dykes, sills and stocks of granite-porphry. The primary ores, consisting mainly of pyrite and chalcopyrite with some zinc-blende and galena, were deposited during and after this last intrusion and were connected with it. The most important ore-bodies occur round the porphyry mass of Sacramento Hill and in faults and fissures where they have replaced the limestone. Oxidation and secondary sulphide enrichment have taken place to a large extent and to great depth, giving rise to chalcocite and bornite and many other secondary copper minerals. Disseminated ores occur in limestone and porphyry, but most of the ore occurs as irregular replacements in limestone without any definite arrangement. This irregularity, together with the treacherous nature of the ground, renders both prospecting and ore extraction comparatively costly.

The Copper Queen mines are the most important producers, their output in 1918 being 40,619 tons of copper, 550 tons of lead, 16,409 oz. gold and 558,433 oz. silver. Most of the ore and concentrates are smelted at Douglas, 30 miles away on the Mexican border. The Sacramento shaft, 1,700 feet deep, deals with the whole of the ore extracted, and has a capacity of 4,000 tons per day.

The Calumet and Arizona Mining Company, in the same district, in 1918 produced 22,727 tons of copper, 31,308 oz. gold and 906,210 oz. silver. The company has its own smelter at Douglas.

The Shattuck Arizona Copper Company, also in the Bisbee district, in 1918 produced 4,054 tons of copper, 1,080 tons of lead, 1,220 oz. gold and 161,230 oz. silver. The ore and concentrates were smelted by the Calumet and Arizona Company.

The Globe-Miami district, in Gila county, was originally opened up for silver ores, but in recent years has become the most important copper producer in the State. The copper deposits of this district are of very different types, dependent largely on the nature of the enclosing rocks. At Globe they occur in lenticular masses replacing limestone, or in dolerite. Most of the ores have

been subjected to a process of secondary enrichment, but some payable primary ores have also been developed. At Miami, six miles west of Globe, the ore minerals are disseminated in the shattered schist and granite in the neighbourhood of the contact.

The Old Dominion Company owns the important Old Dominion and United Globe mines, in addition to a number of others, in the vicinity of Globe City. The principal ore-bodies occur in a fault fissure between "diabase" and limestones and quartzites, and also along the bedding planes of limestone and in shattered quartzite. The copper minerals are cuprite, with small quantities of malachite and chrysocolla in the oxidized zone. In the sulphide zone chalcocite is most abundant, associated with pyrite in a quartz gangue. At depth chalcopyrite also appears. All the ores contain silver. The quantity of water in the mines is very great, and pumping charges constitute an important item of cost. The ore is concentrated by ordinary gravity methods in a mill of 150 tons hourly capacity, the slimes being treated by flotation. The concentrates are smelted and converted by the basic process, yielding blister, containing 99.5 per cent. copper, with small silver values. The smelter production in 1918 was 14,901 tons of copper, 5,071 oz. gold, and 184,982 oz. silver, but part was derived from custom ores. Development at this mine is kept about two years in advance of the mill.

The Miami mine\* has two chief ore-bodies, the larger having maximum dimensions of 1,000 by 750 feet horizontally, but these are connected by narrow necks of ore. In fact, the Inspiration and Miami mines are both on the same ore-body, which is marked on surface as a curved ridge, about  $1\frac{1}{2}$  miles long, in the general direction of the contact between granite-porphry and schist. The latter is silicified where the disseminated copper ore has been deposited. The principal ore mineral is chalcocite, merging into chalcopyrite as depth is attained, associated with varying quantities of malachite and chrysocolla. Cuprite also occurs in small quantities, and native copper rarely. The ore is mined by underground caving methods at the rate of about 5,000 tons per day, and, after crushing, is concentrated by flotation, the coarser tailings from this process being treated on shaking tables and the balance going to waste. The production in 1918 was 26,075 tons of copper, costing 14.83 cents per pound. Ore reserves on January 1st, 1919, amounted to  $54\frac{1}{2}$  million tons, of which 32 million tons were low-grade sulphide ore, containing 1.07 per cent. copper, 11 million tons were high-grade sulphide ore containing 2.38 per cent. copper, and  $5\frac{1}{2}$  million tons were mixed sulphide and oxide ore, averaging 2 per cent. copper.

The Inspiration mine is situated about eight miles west of Globe, and was originally commenced on veins of rich oxidized ore. Subsequently, a large disseminated ore-body was developed which is being mined by block caving methods through two main

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\* The Copper Deposits of Ray and Miami, Arizona; by F. L. Ransome, U.S. Geol. Surv., Prof. Paper No. 115, 1919.

shafts at the rate of about 14,000 tons per day. The ore-body averages about 180 feet in thickness, and is capped by about 100 feet of overburden. The copper minerals consist principally of secondary chalcocite with primary chalcopyrite at depth. The ore is treated by crushing and flotation for recovery of the first concentrates, the tailings being re-treated on gravity concentration machines. Smelting is carried out at Miami at the plant of the International Smelting Company, a branch of the Anaconda Copper Company. The production in 1918 was 43,991 tons of copper, costing 11.26 cents per pound. It is remarkable that these costs were only .82 cent higher than for 1917, considering that the costs of most other companies were doubled during this interval. Ore-reserves amounted to 73,861,826 tons, containing 1.63 per cent. of copper, on January 1st, 1919.

The Morenci-Metcalf district, in Greenlee County and about 80 miles east of Globe, produced 32,083 tons of copper in 1918, the average yield from all ore treated being 1.71 per cent. of copper. The copper ores occur as contact deposits in limestones and shales intruded by porphyry, either disseminated through porphyry or in fault fissures. All the profitable deposits have undergone a process of secondary enrichment, the disseminated type containing chiefly chalcocite. The ores usually contain values in gold and silver, but these are not always recovered, as much of the ore yields copper sufficiently pure for commercial purposes without electrolytic refining.

The Arizona Copper Company is the largest producer in this district, owning mines at Metcalf, Morenci, and Coronado. The Humboldt, Clay and Longfellow mines contain disseminated chalcocite in porphyry dykes; the King mine contains similar ores in faulted areas of porphyry and granite; the Metcalf mine yields oxidized ores from shales and limestones; the Coronado and Horseshoe mines are of a special type, the ore-bodies containing oxidized minerals and disseminated chalcocite, and being found in porphyry, which occupies a fault fissure in granite. Concentrating plants are situated at Clifton and Morenci, the system of treatment being similar to that at Miami. The concentrates are smelted at the company's own smelter, situated 2 miles from Clifton, on the San Francisco River, and converted to blister, which is shipped for refining. The total production of the company in 1918 was 18,054 tons of copper, representing a yield of 1.75 per cent. of copper per ton of ore treated.

The Morenci mines of the Phelps Dodge Corporation include the Ryerson, Arizona Central, Yankee and Copper Mountain mines, all near Morenci. Several types of deposit have been worked, but most of the current production is from sulphide ores disseminated through shattered porphyry. The principal copper minerals are chalcocite, associated with chalcopyrite, and pyrite. In 1918, the production was 7,646 tons of copper.

The output of the Jerome district, in central Arizona, increased considerably during the period under review, being 59,723 tons in 1918, against 15,759 tons in 1913. This was due to the commencement of production by the United Verde Extension Mining Company, which, with the United Verde Copper

Company, are the only important producers. The Verde district is in the Black Hills Range. The ore-bodies are made up of a number of large lenticular masses which replace a fissile sericitic schist, and have a general tendency towards parallelism with the schistosity. As compared with other districts of Arizona, they contain considerable values in gold and silver, especially in the oxidized zone. The chief ore mineral is chalcopyrite, associated with pyrite and zinc-blende. Rich chalcocite ore is also found in considerable quantity, and covellite and other alteration-products occur in the oxidized zone.

The United Verde Copper Company has developed a large ore-body, with extreme dimensions of 600 by 1,900 feet horizontally, and proved to a depth of 1,500 feet. The ore averages about  $6\frac{1}{2}$  per cent. copper, and is sent direct to the crushing plant and smelter, no concentration being attempted. The final product is blister copper. The production in 1918 was a record for the mine, being 34,625 tons of copper, 1,298,414 oz. silver and 29,145 oz. gold. The normal cost is stated to be about 9 cents per pound of copper, after deducting values received for gold and silver. This is one of the great copper mines of the world, and has large reserves of ore for future extraction. The mine has suffered considerably from fire in old workings. The ore thus oxidized is leached with water and an appreciable amount of copper precipitate recovered.

The United Verde Extension Mining Company made a valuable discovery at the end of 1914, after much disappointing exploration work. At a depth of 1,200 feet a rich body of chalcocite ore was encountered, which, at the close of 1915, had been developed for an average width of 150 feet and for a length of 275 feet. It has since been proved for a depth of 400 feet, and one million tons of ore, averaging 16 per cent. copper, are estimated to be available. Blister copper is produced at the smelter. In 1918, the production from 119,227 tons of ore, containing 20.35 per cent. of copper, 54 dwt. gold and 4.68 oz. silver per ton, was 24,773 tons of copper, 3,046 oz. gold and 503,739 oz. silver.

The Mineral Creek or Ray district became an important producer in 1911, and since then it has rapidly come to the front. In 1918 it produced 1,145 oz. gold, 8,395 oz. silver and 37,321 tons of copper from 3,045,536 tons of ore, containing an average of 1.61 per cent. of copper. The deposits and the geological conditions are very similar to those of the Globe district to the north.

The Ray Consolidated Copper Company is by far the most important producer, and has developed a disseminated ore-body of great size. The ore-body is extremely irregular, taking the form of two principal masses connected by narrow necks. The area of the proved ore-body is about 200 acres. It averages 118 feet in thickness in the eastern mass, where it is covered by a barren capping averaging 240 feet in thickness. The western mass averages 171 feet thick and the capping 315 feet. The ore consists of chalcopyrite and pyrite enriched by secondary chalcocite, and occurs in crushed schists and granite. In one part of the deposit the ore is high

grade, running up to 5 per cent. of copper. In the vicinity of "diabase" intrusions, native copper is of economic importance. Underground methods of mining are employed. The ore raised is crushed to about one-inch size at the mine and then sent by rail to the concentrating and smelting plants at Hayden, some 20 miles distant. In 1918, the whole of the production of the district, stated above, came from this mine. The ore-reserves are estimated at 76,128,252 tons, averaging 2.06 per cent. copper.

The Ray Hercules Copper Company has developed a part of the eastern mass, estimated at about 8,500,000 tons, containing 1.77 per cent. copper. The mine is equipped for a production of about 450 tons of copper per month, but the plant was only completed at the end of 1918, since when the copper market has not been favourable for high production.

In the Ajo district\* the New Cornelia Copper Company, a subsidiary of the Calumet and Arizona Mining Company, is the principal producer. The country rock consists of a series of lavas, breccias and tuffs intruded by granitic masses. The disseminated ore-body, which has been developed, was marked at the surface by hills in which occurred veins containing copper minerals. Development has shown an unusual type of disseminated body of commercial grade, although no secondary enrichment appears to have taken place. The deposit outlined by drilling is shaped like a mushroom, of which the stalk has been proved to go down 600 feet from the surface, and to consist of ore of equal value to that in the main upper part of the deposit. The copper minerals, except quite near the surface, are chalcopryite and bornite, disseminated in veins and bunches in the monzonite and extending also into rhyolite. The surface ores have been oxidized into carbonates which merge into sulphides on a horizontal plane corresponding with water-level. The carbonate ore is leached with dilute sulphuric acid and electrolytic copper recovered from the solution. The sulphide ores are concentrated by flotation. All the carbonate ore and part of the sulphide ores are available for open-cast mining by steam shovels. At the end of 1918, 45,821,804 tons of ore, averaging 1.57 per cent. copper, were fully developed, of which about 36½ million tons is sulphide ore. In 1918, 1,659,965 tons of ore mined yielded 13,957 tons of electrolytic copper, 4,907 tons in cement copper and 2,096 tons in ore shipped to smelters, a total of 20,960 tons.

In the Pioneer district, Pinal County, the Magma Copper Company is working ore-bodies in a fault fissure, cutting "diabase," quartzite and limestone, and filled with porphyry in which the principal mineral is chalcocite, with some bornite. Chalcopryite is encountered at a depth of 1,400 feet. The main ore-shoot is about 800 feet long by 9½ feet wide, and, at the 1,800-foot level, averages 5.35 per cent. copper, 4 oz. silver and .2 dwt. gold per ton. In 1918, the net production was 4,896 tons of copper, 463,503 oz. silver and 5,699 oz. gold, the cost being 16.4 cents

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\* Trans. Amer. Inst. Min. Eng., Vol. 49, pp. 593-609.

per pound of copper. Ore-reserves at the end of 1918 were estimated at 210,000 tons of copper sulphide ore, containing 5·7 per cent. copper, 45 dwt. gold and 4·7 oz. silver per ton. A small quantity of silver-lead-zinc ore was also developed.

In addition to the mines above mentioned, there are many other important producers of copper in Arizona.

*California.*—At one time California ranked second only to Michigan among the copper-producing States, and it has been a consistently large producer. Prior to 1897, when production first commenced from Shasta county, most of the copper was derived from mixed ores in which copper was of subordinate importance to silver-lead or pyritic gold ores. The production in 1918 was 19,710 tons of copper, of which 11,174 tons came from Shasta county.

The copper-ore deposits of Shasta county lie in a belt east and west of the Sacramento river. They occur as replacements of alaskite-porphyry in fissures and shear zones. In the western part of the district the ore-bodies are more or less tabular and of small vertical extent, though of considerable size horizontally. In the eastern part they are more of the vein type and occur in sedimentaries adjoining the porphyry as well as in the porphyry itself. The copper mineral of the sulphide lenses is chalcopyrite associated with pyrite and zinc-blende, the latter often occurring in sufficient quantity to constitute a zinc ore. The ores contain values in precious metals, especially in the eastern district, where they become important.

The Mountain Copper Co., Ltd., owns the Iron Mountain and Hornet mines, ten miles north-west of Redding. The Iron Mountain mine was originally worked for the rich silver values contained in the gossan, overlying a lens of ore the maximum dimensions of which were 400 feet wide by 800 feet long by 500 feet deep, the sulphide ore consisting of chalcopyrite and pyrite, averaging about 5 per cent. copper and nearly 1 dwt. gold and 2 oz. silver per ton. The rich ore is now exhausted. At the end of 1918, there were about 250,000 tons of pyritic ore developed. The Hornet mine, north of Iron Mountain, contains about  $4\frac{1}{2}$  million tons of pyrite ore, averaging about 1 per cent. copper and 48 per cent. sulphur. Values in precious metals are low, but, as the ore is employed for manufacture of sulphuric acid, they are recovered with the copper. About 600 tons of ore are mined daily at Iron Mountain and 450 tons at the Hornet mine. Part of the ore is concentrated by gravity methods and part in a flotation plant of 450 tons daily capacity. The company owns a smelter at Martinez, on San Francisco Bay, where custom ore is treated and considerable quantities of sulphuric acid are manufactured. In 1918, the production was 3,037 tons of copper.

The Balaklala Consolidated Copper Company owns mines in the Flat Creek district, four miles north-east of Iron Mountain. Ore-reserves are stated to be about  $2\frac{1}{2}$  million tons, containing 2·83 per cent. copper, 1·5 oz. silver and 7 dwt. gold per ton. The ore was smelted to blister copper at the company's own

smelter at Coram, but difficulties have been encountered owing to questions of damage to agriculture by the fumes.

In the Foothill district the most important producer is the Calaveras Copper Company, owning the Union, Keystone and Empire mines, 16 miles from Milton. Lenticular ore-bodies occur in a wide shear zone in a basic igneous rock of schistose character. A crushing and flotation plant of 600 tons capacity per day is installed and also a smelter of 350 tons daily capacity. Large quantities of ore are said to be available, containing 3 per cent. copper, but production had been intermittent up to 1919.

In Plumas county the principal production is from the Engel and Superior groups, belonging to the Engels Copper Mining Company. A number of ore-bodies are being developed in porphyry near its junction with diorite. The lenses are of large size and contain bornite, with some chalcocite and chalcopyrite, averaging about  $2\frac{3}{4}$  per cent. copper in the Engel group. The average ore in the Superior group contains 2 per cent. copper, but there are large lenses containing from 15 to 20 per cent. Ore-reserves are reported to be about three million tons and a further 10 million tons probable. The mines are equipped with a flotation plant of 500 tons daily capacity at the Engel mine and another of 1,000 tons capacity at the Superior mine. The Superior mill is being increased to 2,000 tons daily capacity. The production has increased rapidly since it began in 1915, and amounted to 4,205 tons of copper in 1918, costing 19.58 cents per pound. In addition, 1,108 oz. gold and 119,708 oz. silver were obtained. The average grade of ore milled was 2.23 per cent. copper.

*Michigan.\**—The whole production of this State comes from the Lake Superior district, where copper was mined by the Indians before European settlement took place. Since 1845 the district has been an important producer and for many years the principal one in the United States. In 1918, the production was 103,168 tons of copper, from 10,108,362 tons of ore treated, averaging 0.96 per cent. copper. Although an important amount has been produced annually for the past 70 years, many mines still have large reserves and new mines are being opened. Extensive areas still remain to be prospected. The region is unique in being the only one in which large outputs are obtained where the copper occurs in the native form. The whole production comes from Keweenaw Point, a sharp promontory reaching out on the south shore of Lake Superior. The copper-producing area stretches for 70 miles in a north-easterly direction, and has a width of from two to three miles. The Keweenawan Series comprises a thick series of basic lava flows intercalated with beds of conglomerate and sandstone. The copper deposits occur in veins traversing the series in the north-east end of the district and parallel with the beds in the south-west at Ontonagon, and as

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\* *Geology of the Lake Superior District*; U.S. Geol. Surv. Monograph No. 52, pp. 35-38, 573-591.



bedded deposits in the central productive part of the region. Although a considerable production has come from the veins in the past, they are of little economic importance at the present time. The bedded deposits have been formed by infiltration or replacement of the amygdaloids and conglomerates. The lodes vary in width from a few feet up to 40 feet in the amygdaloidal beds and from 13 to 20 feet in the conglomerate.

The amygdaloids are by far the most productive and numerous. At the surface quantities of black sulphides of copper are found, but not in payable amounts. The valuable copper occurs native in cavities in amygdales partly filled by other minerals which have been fractured and cleaved, thus providing planes in which the copper has been deposited. The alteration of these beds has been so extensive in places that the amygdaloidal character has been lost. The copper is found in highly diverse forms from minute grains to branches and even massive form, individual masses being found up to several hundred tons in weight. The conglomerate beds are numerous, but only two of them have proved to be economically productive, and then only for a comparatively restricted length. The most important properties of the district, belonging to the Calumet and Hecla Mining Company, are, however, situated on a conglomerate bed. On the average, the bedded deposits are of low grade, but of large extent and comparatively regular. The Kearsage amygdaloidal lode has been found productive for a length of 14 miles, and a depth of over 8,000 feet has been reached on the dip in one mine. Immense plants have been erected for the treatment of the ore, which is easily concentrated and cheaply smelted to very pure copper. "Lake" copper commanded a substantial premium over other brands on account of its purity until the introduction of electrolytic refining, and still commonly sells at a slightly higher price. A considerable amount of the ore mined contains native silver, but this is not always recovered. About 20 per cent. of the annual output is refined electrolytically in order to recover the silver. The crude ore is usually crushed by special steam stamps and concentrated by ordinary wet gravity methods. In recent years much copper has been recovered by re-grinding and treatment of tailings, which previously had been discarded, and the flotation process has now been adopted both for ore and tailings. The concentrates average about 65 per cent. copper. Ores are being mined in this region from a depth of over a mile and treated at a profit, although very considerably poorer than the low-grade "porphyries" mined by steam-shovel at the surface.

The Calumet and Hecla Mining Company is said to be the premier dividend-paying mine of the world, having paid £31,000,000 on a capital of £240,000. The company started operations on the conglomerate beds of the Calumet and Hecla claims, but has now secured control of a number of other companies operating in the region, and has further

large interests in others without actually having full control. Although the conglomerate bed has proved so productive in this company's ground, it has not been so in other properties adjoining, both to the north and to the south along the strike. The bed is opened up for about two miles on the strike and to a vertical depth of 4,900 feet at the Red Jacket shaft, followed by a further 1,588 feet by an incline shaft. Several shafts on the property are over a mile deep. The thickness of the conglomerate bed averages about 13 feet and varies between 5 and 26 feet. The average tonnage per acre is about 38,500 tons. The ore has steadily declined in value in depth, and the recovery is now about 12 lb. of copper per ton of ore mined as against about 104 lb. in the early part of the company's career, actual production having started in 1866. In addition to the Calumet conglomerate bed, the company is also producing from the Osceola amygdaloid bed, which underlies the conglomerate and averages about 35 feet in thickness, containing fair values in the Tamarack property at a vertical depth of nearly a mile. The Kearsage amygdaloid bed underlies the Osceola lode and has been opened up for about 2,000 feet from surface, but is not at present being worked. The values are erratic, but the bed is said to be payable by selective mining. The total production in 1918 was 30,343 tons of copper, costing 21.05 cents per pound, obtained from 2,568,207 tons of ore, yielding 22'87 lb. of copper per ton. There has been a considerable decline in production since 1906, when the record output of 44,653 tons of copper was reached.

The Ahmeek Mining Company is working on the Kearsage lode. The production in 1918 was 11,094 tons, being a yield of 23'29 lb. per ton of ore treated. Ore reserves amounted to  $4\frac{1}{2}$  million tons.

The Champion Copper Company owns one of the richest mines of Lake Superior, the beds developed being payable throughout the property. Four amygdaloidal beds are being worked, the principal one being known as the Baltic. This dips steeply, *i.e.*, at about  $70^{\circ}$ , and averages 24 feet in thickness. It contains comparatively rich ore, the copper occurring mostly massive of "barrel" size, but also in solid pieces up to 10 tons in weight. In 1918, 530,567 tons of ore mined yielded 9,709 tons of copper, being an average yield of 40'99 lb. per ton of ore treated.

The Osceola Consolidated Mining Company owns several distinct areas and obtains its production from the Osceola amygdaloid lode and the Kearsage. In 1918, the total production was 7,107 tons of copper from 1,066,935 tons of ore, representing a yield of 14'89 lb. of copper per ton of ore treated. The average cost per pound of copper was 17.67 cents.

The Quincy Mining Company has a continuous dividend-paying record from 1868. The Company owns very extensive properties and is estimated to have a further life of nearly 60 years and a further production of 535,000 tons of copper. The principal workings are in the Pewabic amygdaloid bed, which has been worked down for 8,000 feet from surface on the incline. The values are very uniformly distributed, and practically the

whole thickness of the bed is mined. In 1918, the production was 8,905 tons of copper, an average yield of about 19 lb. per ton of ore. The cost was 18.7 cents per pound of copper. A considerable quantity of silver is recovered as a silver-copper alloy in the Company's smelter. One shaft has been equipped with hoisting gear capable of raising a 10-ton load of ore from a vertical depth of 10,000 feet.

The Isle Royale Copper Company's mine is low-grade but profitable. Three amygdaloid beds are worked, the principal ones being the Baltic and Portage, but other beds and veins containing copper are known to exist on the properties. The production in 1918 was 6,894 tons of copper from 870,096 tons of ore, being a yield of 17.8 lb. of copper per ton of ore. The cost was 16.5 cents per pound of copper.

The Mohawk Mining Company's property contains the Kearsage lode, which averages 15 to 18 feet in thickness. This is crossed by a number of almost vertical fissure veins, containing much barrel copper and a number of minerals of the copper arsenide group. In 1918, the production was 4,813 tons of copper from 405,619 tons of ore, an average yield of 26.58 lb. of copper per ton.

The Baltic mine, owned by the Copper Range Company, produced, in 1918, 4,645 tons of copper from 262,144 tons of ore, being a yield of 38.57 lb. of copper per ton. This is the highest yield shown by any mine in the district except the Champion mine. The cost was about 15 cents per pound of copper.

*Montana.*—Practically the whole production of Montana comes from the Butte district, which has yielded over 28 per cent. of the total output of the United States, and was the premier district both in total output and also for the year 1918, when the production was 121,840 tons of copper, 64,318 oz. gold and 10,076,748 oz. silver. The district first attracted attention in 1864, when gold was discovered, silver subsequently becoming the chief product. Copper only became of real importance with the advent of a railway in 1881. The copper ores occur as replacement veins in fractures and fault fissures in a quartz-monzonite. The veins form complex systems, varying in strike and of slightly different age. The copper minerals, in order of importance, in the sulphide zone are chalcocite, enargite, bornite, chalcopyrite, tetrahedrite, tennantite and covellite. In the oxidized zone chrysocolla, malachite, cuprite and native copper are common, but they have not contributed materially to the total output. About 60 per cent. of the output of the district has come from chalcocite ores, but, as the mines have reached greater depth, an increasing proportion has been derived from enargite and bornite, the amount derived from the two last-named minerals being now about equal to that from chalcocite. The latter mineral is both primary and secondary, and is abundant in both forms. The mines have now reached a depth of 3,000 feet, at which point the chalcocite is nearly all primary. From this it is inferred that no sudden impoverishment need be apprehended as greater depth is attained. The grade of ore mined is to some

extent determined by current costs and selling prices, but there has been a steady fall in the yield per ton during the past decade. The following table shows the record of the district during the period under review :—

Year	Yield per ton of ore			Total production of Copper (long tons)
	Copper (per cent.)	Gold (oz.)	Silver (oz.)	
1913     ...     ...	2·70	·0065	2·15	126,607
1914     ...     ...	2·66	·0066	2·05	105,223
1915     ...     ...	2·66	·0074	2·04	119,196
1916     ...     ...	2·81	·0066	2·00	156,027
1917     ...     ...	2·81	·0063	2·06	120,759
1918     ...     ...	2·17	·0066	2·27	143,350
1919     ...     ...	2·16	·0080	3·01	75,469

The ore mined falls into two classes, viz., direct-smelting ore and concentrating ore. The latter is crushed and concentrated on jigs and tables and by the flotation process.

The Anaconda Copper Mining Company is an amalgamation of nearly all the important mines in the Butte district, and is the largest copper company in the world. Its interests in the metal cover the mining, smelting and refining, and follow on to the manufacture of copper wire, rods and brass. In addition, the company produces important quantities of electrolytic zinc and by-products of various kinds. The deepest shaft on the property, on the High Ore mine, is down 3,600 feet, and ore is being extracted from a depth of 3,400 feet, where large ore-bodies exist in fault veins. The equipment of the Leonard mine is the most complete at Butte. Much trouble has been experienced from underground fires, the St. Lawrence mine having been on fire since 1889. Very complete fire protection and ventilation has been organized for all mines. In 1918, 4,391,489 tons of ore were mined, and 5,851 tons of copper precipitate were obtained from the mine waters. The reduction plant treated a considerable quantity of custom ore in addition to 3,884,327 tons of company ore, which yielded 121,840 tons of copper, 64,318 oz. gold and 10,076,748 oz. silver.

The leaching plant at Anaconda treated 447,042 tons of tailings and 58,016 tons of ore for a production of 5,948 tons of copper precipitate. The ore is concentrated at Washoe, two miles from Anaconda and 26 miles from Butte, where also it is nearly all smelted. Concentration is effected by a combination of gravity and flotation machines. The Washoe smelter has a capacity of 14,000 tons of ore per day, and was re-modelled in 1915 at a cost of £1,200,000. This amount is said to have been entirely repaid during the first six months' operation from increased saving of copper, i.e., from 75 to 96 per cent. recovery. Reverberatory furnaces, fired by coal dust, deal with most of the ore.

At Great Falls, 130 miles from Butte, most of the power for the Butte mines and Washoe smelter is generated, and transmitted at a pressure of 50,000 volts. Here also the electrolytic refinery is situated, having a capacity of about 90,000 tons per annum, and the copper rod and wire factory. There is also a large electrolytic zinc refinery, and it is suggested that the manufacture of brass will be undertaken also. Ore-reserves and costs are not published by the company, but it would appear that the normal cost is about 9 cents per pound of copper produced.

The East Butte Copper Mining Company owns the Pittsmont group of mines and a smelting plant at Butte. Custom ore is smelted in addition to the products of their own mines. In 1918, the total output was 10,982 tons of copper, 1,419 oz. gold and 776,818 oz. silver.

The North Butte Mining Company, in 1918, produced 9,232 tons of copper, 1,375 oz. gold and 891,157 oz. silver. The Granite Mountain shaft is down to 3,700 feet and is equipped for a depth of 5,000 feet. The electrically driven winding engine is capable of raising a load of seven tons of ore and making a round trip from this depth in two minutes. The ore is smelted by the Anaconda Copper Company at the Washoe works.

*Nevada.*—The importance of Nevada as a copper-producing area is of comparatively recent date, beginning from 1908, when production from the Ely district commenced. In 1918 the production of the State was 47,440 tons of copper.

The Ely district\* contains the Nevada Consolidated mine, which is responsible for the greater part of the output. The deposits are of the disseminated type in greatly altered and shattered quartz-monzonite-porphry. Pyrite and chalcopyrite are the chief primary ore minerals, but the profitable ore has been enriched by secondary chalcocite, which is found enclosing and replacing grains of the primary minerals. The leached capping varies in thickness, upon which depends the method of mining. Less important deposits of copper ore occur as replacements of limestone which has been intruded by the monzonite, and are usually closely connected with the intrusive.

The Nevada Consolidated Copper Company, controlled by the Utah Copper Company, has developed a number of ore-bodies at Ely, the most important being known as the "Copper Flat," "Ruth" and "Veteran." The "Copper Flat" is worked opencast by steam shovels. The ore-bearing porphyry occurs as a blanket-like body, about 3,000 feet long, from 400 to 1,200 feet wide and from 200 to 500 feet thick. In outline it resembles a dumb-bell, and is worked in three sections, known as the Liberty, Hecla and Eureka pits. The leached and oxidized capping varies in thickness from an average of 87 feet at the Eureka pit to 154 feet at the Liberty end of the ore-body. The corresponding thickness of ore is 190 and 193 feet, respectively. It is anticipated that about one ton of overburden will require to be removed for every ton of ore recovered. The dividing lines between capping and ore and between ore and unenriched

porphyry are very irregular, owing to unequal penetration of leaching and depositing solutions down fissures and joint planes. About 9,000 tons of ore and 12,500 tons of overburden are mined daily. The Ruth ore-body, about  $1\frac{1}{4}$  mile east of the Copper Flat, has a capping from 110 to 540 feet in thickness, which is too much for opencast mining. It is, therefore, worked by a special caving system\* through two main shafts. The daily output of ore is about 4,500 tons. The Veteran ore-body is not at present being worked. The ore developed in the mine amounts to 139,107 tons, containing 3.89 per cent. copper.

The ore from all the mines of this company is transported to McGill, in the Steptoe Valley, north-east of Ely, and about 22 miles from the mines. The ore-reserves on December 31st, 1918, were given as 61,205,039 tons, averaging 1.57 per cent. copper. The production for the year was stated to be 3,571,000 tons of ore, assaying 1.5 per cent. copper and yielding 34,200 tons of copper at a cost of 17.98 cents per pound.

The Consolidated Copper Mines Company is working disseminated ore-bodies at the Morris-Brooks and Ova mines and contact replacement deposits at the Alpha mine. The company holds very extensive properties, which have not yet been thoroughly explored. In 1918, the production was 7,039 tons of copper, 4,338 oz. gold, and 17,415 oz. silver from 443,565 tons of ore. Ore-reserves at the end of the year were about  $17\frac{1}{2}$  million tons of disseminated ores, averaging 1.33 per cent. copper, in addition to small quantities of heavy sulphide ore and oxidized ore containing from 3 to 8 per cent. copper.

The Mason Valley mine, at the south-east corner of the State, is on a contact metamorphic zone between limestone and andesite, and contains an ore-body averaging about 30 feet in width, which has been developed to a depth of 550 feet. Most of the ore is primary, containing chalcopyrite and pyrite, but for about 100 feet from surface oxidized minerals and secondary sulphides also occur. The limestone, which has been replaced, is very highly altered to a garnet rock. The ore is delivered from the mine to the railway by an aerial ropeway and is sent to the Company's smelter near Wabuska, 16 miles distant. The ultimate product is blister copper. In 1918 the Company smelted 300,842 tons of ore and 10,437 tons of metal-bearing fluxes, 195,450 tons being custom ore. The production was 6,908 tons of blister copper, 809 oz. gold, and 91,824 oz. silver. In June, 1918, it was reported that drilling had proved 830,000 tons of ore, averaging  $\frac{1}{2}$  dwt. gold per ton and 3.04 per cent. copper, and 446,000 tons of ore, averaging 0.2 dwt. gold per ton and 1 per cent. copper.

*New Mexico.*—Copper was produced in New Mexico in the 18th century, when native copper was sent to Mexico for coinage purposes. Important production, however, only began in 1912. The output of the State for 1918 was 43,107 tons of copper. The most important districts are Santa Rita, Burro Mountain and Lordsburg, of which the first is by far the chief producer, owing to the operations of the Chino Copper Company.

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\* Trans. Amer. Inst. Min. Eng., Feb., 1918.

The Chino Copper Company's property is situated in the south-east part of the State and is about 100 miles east of the Morenci mines in Arizona. The ore-body is of the disseminated type and of considerable extent. Unlike most of the disseminated ores, there is an appreciable amount of native copper present. The geology is somewhat complicated. Sedimentary rocks consisting of quartzites, shales and limestone have been intruded by rocks of the quartz-monzonite-porphyry type. Extensive faulting has taken place with consequent shattering of the rocks, the principal ore-body occurring in a roughly circular shear zone, about three-quarters of a mile in diameter, at the intersections of numerous faults. The ore consists of chalcocite, cuprite and native copper with lesser amounts of bornite, chalcopyrite and pyrite and oxidized minerals, such as malachite and azurite, in restricted areas. The mine is worked by steam shovels, about 1 ton of overburden being removed for every ton of ore. The ore is concentrated at Hurley, 9 miles from the mine, in a mill of about 10,000 tons daily capacity. The recovery varies considerably according to the composition of the ore. Concentrates are shipped to El Paso, Texas. In 1918 the production was 33,775 tons of copper, costing 17.17 cents per pound. This was obtained from 3,425,357 tons of ore treated, containing 1.63 per cent. copper and 1.22 cent value in gold and silver per ton. The copper represented a mill recovery of 63.27 per cent. A large quantity of tailings is available for the retreatment plant. Ore-reserves, at the end of 1918, were estimated at 86,207,166 tons averaging 1.63 per cent. copper.

The Burro Mountain mines,\* in the Burro Mountain district, owned by the Phelps Dodge Corporation, increased their production considerably during the period under review. Several ore-bodies are being developed in fracture zones near the contact of Cambrian granite intruded by quartz-monzonite-porphyry, in both of which rocks disseminated ores occur, consisting of primary cupreous pyrites enriched by secondary chalcocite. Ore-bodies containing the same materials also occur in veins near the contact. The properties are near Tyrone and Leopold, about two miles apart, in Grant county, and about 30 miles west of the Chino property. A gravity concentration and flotation plant with a daily capacity of 1,500 tons of ore is in operation. The production in 1918 was 6,780 tons of copper and 43,150 oz. silver, the ore milled being 522,396 tons, averaging 1.92 per cent. copper. A small quantity of copper was recovered from leaching beds at the mines. A considerable quantity of ore has been disclosed by drilling operations.

*Tennessee.*—The copper production of this State is all from the neighbourhood of Ducktown, in the extreme south-eastern corner, and amounted in 1918 to 6,720 tons of copper, an average yield of 1.42 per cent. from the ore with 20 cents per ton in gold and silver. The deposits occur in an area of the southern Appalachian Mountains, characterized by complex geologic relations and

\* Trans. Amer. Inst. Min. Eng., Vol. 52, pp. 604-644. U.S. Geol. Surv. Bull. 470c, 1910, pp. 3-22.

extensive metamorphism. The ores consist principally of pyrrhotite, with smaller amounts of pyrite, chalcopyrite, zincblende and galena in a lime-silicate and quartz gangue. The ore-bodies are lenticular, and occur in sedimentary rocks as replacement deposits of limestone, usually parallel with the bedding planes of the enclosing rocks. The area in which they are being worked is six miles by four miles. The ore-bodies vary in width up to 500 feet, and in length up to 2,000 feet, and have been proved to a depth of over 1,500 feet. There is usually a large gossan capping, succeeded by an enriched zone of secondary chalcocite. Small values in gold and silver are general, but are not always recovered. The copper output of the district has been restricted by the introduction of legislation limiting the amount of sulphur which may be discharged with the smelter fumes into the atmosphere. This led to the manufacture of sulphuric acid, which is now to be utilized in the manufacture of fertilizers on a large scale. The treatment of these ores has been an interesting development. Originally the rich chalcocite ores were exploited, but on exhaustion of these the lower-grade pyritic ores were treated by heap roasting, followed by smelting. Later, semipyrritic smelting was adopted, the first matte undergoing a secondary fusion in order to raise the copper content before conversion. This has now been abandoned, and the first matte from the blast furnace is sent straight to the converter. Blister copper is shipped to electrolytic refiners for extraction of small values in gold and silver. Recently, new developments in treatment of the ore before smelting have been introduced, which may revolutionize the whole smelting practice. By differential flotation it has been found possible to make a chalcopyrite concentrate containing about 18 per cent. copper, and a pyrrhotite concentrate practically free from copper. It is expected now not only to recover the copper and sulphur values, but also to obtain a high price for the sintered residues from roasting as an iron ore.

The Tennessee Copper Company owns the Burra Burra, London, Polk county and Eureka mines. The Burra Burra is the principal mine, containing several ore-bodies, and supplied the greater part of the output in 1918. The Eureka mine was not then being worked, and the Polk county only supplies a siliceous flux. The company has the most complete sulphuric acid plant in existence, having a capacity of 320,000 tons of 50° Baumé acid per annum, most of which is to be employed in the manufacture of superphosphate by the company or by other makers of fertilizers. In 1918, 358,992 tons of ore were treated, yielding 4,384 tons of copper at a cost of 18.52 cents per pound, and 252,760 tons of sulphuric acid. Ore-reserves at the end of 1919 were 3,136,210 tons.

The Ducktown Sulphur, Copper and Iron Co., Ltd., owns the Mary, East Tennessee, Isabella, and Cherokee mines, and has large reserves of sulphur.



copper, with low values in gold and silver. The first successful sulphuric acid plant working on fumes from pyritic smelting was erected by this company. The Mary mine, which is the principal producer, has  $1\frac{1}{2}$  million tons of ore proved and an equal quantity of probable ore averaging 1·8 per cent. copper and 16 per cent. sulphur. The East Tennessee mine produces about 25 tons per day of ore, containing from 3 to 5 per cent. copper and 8 per cent. sulphur. Reserves are estimated at about 6,700 tons, containing  $2\frac{1}{2}$  per cent. copper and 8 per cent. sulphur. The Isabella mine has been explored by diamond drilling, and is reported to have  $6\frac{1}{2}$  million tons of probable ore, averaging 0·8 per cent. of copper and 29 per cent. sulphur. The Cherokee mine is expected to yield between  $3\frac{1}{2}$  and  $4\frac{1}{2}$  million tons of ore, averaging 1 per cent. copper, 29 per cent. sulphur, and 45 per cent. iron. The ore is smelted to a matte containing 45 per cent. copper, which is sold. A differential flotation plant of about 250 tons daily capacity has been installed. The production in 1918 was 2,345 tons of copper and 31,000 tons of 60° Baumé sulphuric acid.

The Copper Pyrites Corporation owns a property on which there is a gossan outcrop three-quarters of a mile long. Diamond drilling has proved about  $1\frac{1}{2}$  million tons of ore, containing 45 per cent. iron, 29 per cent. sulphur, and 1 per cent. copper, and  $10\frac{1}{2}$  to  $11\frac{1}{2}$  million tons are considered probable.

*Utah.\**—Utah ranked fourth amongst the copper-producing States during the period under review, the output for 1918 being 103,109 tons of blister copper. The principal producing districts are Bingham and Tintic, the former contributing about 90 per cent. of the whole output of the State.

The Bingham district contains two types of copper ore deposits: (a) irregular replacement deposits in limestone, and (b) disseminated deposits in altered porphyry and quartzite. The former contain values in galena and zinc-blende, gold and silver, in addition to copper, and were the chief source of copper ore in the district in former years. The disseminated ores are now, however, by far the most important. Both types are closely associated with masses of monzonite-porphyry, intruded into quartzites intercalated with beds of limestone and shale.

The replacement deposits are massive bodies of pyrite with varying quantities of chalcopyrite grading, in places, into ores of galena and zinc-blende. They usually occur near the porphyry and about fissures in the limestones. The process of secondary enrichment has not extended to great depth, and the copper content of the ores varies largely.

The disseminated ores consist of veinlets and grains of pyrite and chalcopyrite as primary minerals, with secondary covellite, chalcocite, and bornite. The porphyry ore is overlain by a considerable depth of capping, the thickness of which has largely determined the state of alteration of the porphyry ore and the depth to which secondary enrichment has been carried.

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\* Prof. Paper 111, U.S. Geol. Surv. 1920. Trans. Amer. Inst. Min. Eng., Vol. 54, pp. 356-401.

The Utah Copper Company owns the greater part of the porphyry mass, which is sufficiently enriched to constitute payable ore. The ore-body forms an isolated hill, about 1,600 feet high, between the Carr Fork and Bingham Canyons, the dimensions being approximately one mile in length and half a mile in width. The capping has a thickness at one end of over 200 feet, and at the other end of about 75 feet, the average thickness over the whole area of 226 acres of ore-body developed in 1914 being 115 feet. The ore-body has been proved for an average depth of 556 feet, and the calculated ore-reserves at the end of 1918 were estimated at 333,964,285 tons, averaging 1.370 per cent. copper. With the exception of the Chuquicamata mine in Chile, this is the largest developed ore-body known. The quantity of ore treated per annum is greater than at any other mine. Originally the deposit was opened up and worked by underground methods, but later it became apparent that the ore could be more profitably treated by stripping the overburden and mining the ore by steam shovels. The change over has been gradually carried out. The ore milled has gradually increased from 6,713,743 tons in 1913, to 10,857,768 tons in 1918, the corresponding quantities of refined copper produced being 50,867 tons and 83,970 tons respectively. The value of gold and silver recovered is about  $\frac{3}{4}$  cent per pound of copper. The costs were about 8 cents per pound before the war, but in 1919 they were 12.3 cents. The ore mined is sent to two concentrating mills at Garfield, 20 miles away, known as the Magna and Arthur mills. The Magna mill has a capacity of about 18,000 tons of ore per day. Concentration is effected on tables and vanners. A leaching plant for treatment of the oxidized capping ore is situated near the Magna mill, and has a daily capacity of about 1,100 tons. The ore is leached by sulphuric acid, and copper precipitate recovered on scrap iron. The Arthur mill has a capacity of about 14,000 tons of ore per day.

*Utah Copper Company*

Year	Ore mined and milled (long tons)	Copper content (per cent.)	Mill recovery (per cent.)	Refined copper produced (long tons)	Cost in cents	
					Per lb of copper*	Per ton of ore
1913 ...	6,713,743	1.25	63.95	50,867	8.64	108
1914 ...	5,776,934	1.42	66.04	51,647	7.25	106
1915 ...	7,584,196	1.43	64.13	66,249	6.61	95
1916 ...	9,816,071	1.43	62.34	83,720	6.92	104
1917 ...	11,198,214	1.33	61.10	87,427	10.95	158
1918 ...	10,857,768	1.22	65.11	83,970	14.53	197
1919 ...	4,945,268	1.26	78.46	46,915	12.36	224

\* Net cost after deducting value of precious metals and railway earnings.

The Utah Consolidated Mining Company owns the Highland Boy and other groups of adjoining mines in the Carr Fork Canyon. The ore-bodies are replacement deposits in limestone, and contain both copper and lead ores. They vary from 4 to 320 feet in width by 100 to 340 feet in length. The principal copper

minerals are chalcopyrite, bornite, and chalcocite, associated with pyrite. The maximum production of this mine was 8,273 tons of copper in 1906, since when there has been a gradual decline in output, the quantity for 1919 being 2,549 tons. At the end of 1919, reserves of copper ore amounted to 757,000 tons, containing 1.94 per cent. copper, 0.9 dwt. gold, and 14.8 dwt. silver per ton. The mines also produce important quantities of lead ores containing gold and silver.

*Other States.*—Colorado and Idaho have appreciable outputs of copper ores, but most of the production is incidental to the mining of ores of other metals, principally lead and zinc.

Copper ores are also obtained in the States of Georgia, Oregon, Vermont, Washington and Wyoming.

*Copper Ores produced in the United States and average yield of Copper, Gold, and Silver*

(Mineral Resources of the United States, Annual)

Year	Copper* Ores (long tons)	Yield of Copper (per cent.)	Yield of Gold per ton (oz.)	Yield of Silver per ton (oz.)
1913 ... ..	32,443,466	1.67	0.0064	0.562
1914 ... ..	31,406,733†	1.60	0.0084	0.473
1915 ... ..	38,753,734	1.66	0.0087	0.479
1916 ... ..	51,663,719	1.70	0.0077	0.475
1917 ... ..	52,216,691	1.60	0.0065	0.389
1918 ... ..	55,615,240	1.51	0.0056	0.367
1919 ... ..	32,251,448	1.65	0.0058	0.399

\* Copper is also derived from small quantities of ores classed as lead ores and siliceous ores.

† Includes 89,121 tons of slag smelted and ore leached.

*Production of Copper in the United States*

(long tons)

(Mineral Resources of the United States, Annual)

Year	Mine* Production	Smelter† Output	Refined‡ Copper	Secondary§ Copper
1913 ...	551,594	546,644	721,012	121,875
1914 ...	512,693	513,453	684,724	114,180
1915 ...	664,318	619,646	729,555	175,167
1916 ...	895,479	860,646	1,008,655	312,500
1917 ...	846,175	842,017	1,084,172	342,321
1918 ...	852,689	852,023	1,085,886	314,884
1919 ...	541,221	574,294	805,940	256,420

\* Estimated recoverable copper content of ore despatched from mines.

† Actual quantity of crude copper recovered from the ores, including copper from sulphur, lead, zinc and siliceous ores which carry so little copper that the mines are not paid for it, and frequently do not report it.

‡ Including domestic and foreign electrolytic, lake, casting and pig copper.

§ Material recovered from remelting old copper, copper scraps, and copper recovered from the treatment of copper alloys or alloys that are treated without the separation of copper.

*Production of Refined Copper in the United States*  
(Mineral Resources of the United States, Annual)

	Quantity (long tons)							
	1913	1914	1915	1916	1917	1918	1919	
From Primary Sources :—								
Domestic :—*								
Electrolytic ...	456,472	442,667	497,475	705,188	648,546	696,575	550,890	
Lake ...	69,516	70,540	105,695†	120,444	119,870	103,168	79,283	
Casting ...	10,092	9,601	9,623	5,566	31,213	6,823	8,136	
Pig and best select ...	16,073	17,560	6,718	11,995	36,775	34,003	1,640	
Total	552,153	540,368	619,511	843,193	836,404	840,569	639,949	
Foreign :—*								
Electrolytic ...	168,859	144,356	110,044	165,462	247,768†	219,724†	165,428†	
Casting and best select						25,593	563	
Total	168,859	144,356	110,044	165,462	247,768	245,317	165,991	
Total from Primary Sources	721,012	684,724	729,555	1,008,655	1,084,172	1,085,886	805,940	
From Secondary Sources	121,875	114,180	175,167	312,500	342,321	314,884	256,420	
TOTAL Refined Copper	842,887	798,904	904,722	1,321,155	1,426,493	1,400,770	1,062,360	

\* The separation of refined copper into metal of domestic and of foreign origin is only approximate, as an accurate separation at this stage of manufacture is not possible.

† Some Lake copper was refined at seaboard plants and doubtless marketed under some brand other than Lake. This has been excluded from the Lake copper.

‡ Includes refined copper imported

*General Imports of Copper into the United States*  
(Mineral Resources of the United States, Annual)

	Quantity (long tons)							
	1913	1914	1915	1916	1917	1918	1919	
Ors (copper content) ... ..	48,531	46,786	{ 51,041 }	55,750	52,009	34,318	22,195	
Concentrates (copper content) ... ..				14,622	17,052	20,655	16,256	
Matte and regulus (copper content) ... ..				7,659	9,397	15,213	18,002	
Unrefined black copper and copper in bars, pigs, or other forms. ... ..	133,959	89,977	{ 89,896 }	120,057	158,749	168,916	117,509	
Refined in bars, plates, rods, or other forms ... ..				3,755	3,014	17,003	15,687	
Old and clippings for remanufacture ... ..				4,219	7,988	858	1,883	
Composition metal, copper being chief value ... ..				338	192	93	- 159	
TOTAL	182,490	136,763	140,937	206,400	248,401	257,056	191,691	

*Exports of Copper from the United States*  
(Mineral Resources of the United States, Annual)

	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Ore (copper content) ... ..			695	2,151	2,293	1,066	226
Concentrates (copper content) ... ..			139	431	367	390	72
Unrefined black blister and converter copper (bars, pigs, and other forms) }	365,228	334,331	551	8,153	7,586	6,557	747
Refined in ingots, bars, rods, or other forms			262,305	319,918	460,169	308,048	195,607
Composition metal, copper chief value ...			—	—	548	83	163
Old and scrap ... ..			69	364	478	115	201
Pipes and tubes ... ..			—	—	3,241	1,834	2,676
Plates and sheets ... ..	29,859	23,996	16,062	11,091	19,047	8,693	6,145
Wire ... ..	16,924	14,575	22,521	10,477	12,000	7,004	24,800
All other forms ... ..	1,578	40,999	2,919	—	—	—	—
TOTAL ... ..	413,589	413,901	305,261	352,585	505,729	333,790	230,637

### Argentina\*

The principal copper-mining undertaking in Argentina is the Famatina, in the Mejicana district, province of Rioja, which includes the Upulungos, San Pedro, Mellizas, and Compañía groups. These mines lie at an elevation of about 15,000 feet in two ridges separated by Mejicana gulch. The copper deposits occur in veins, usually in slate, connected with intrusions of granite, pegmatite, diorite and quartz-andesite, intersecting the highly metamorphosed slate. They contain enargite, famatinite, tetrahedrite, and chalcopyrite, with some pyrite, galena, and blende, in a quartz gangue, with a little calcite and barytes.

The San Pedro vein has a width of from 12 to 25 inches. The ore shoot is about 600 feet in length, and averages 11.5 per cent. copper, 2.6 oz. silver, and 0.3 oz. gold per ton. The Upulungos vein, which runs parallel to the San Pedro, is said to be from 24 to 44 inches wide and has been developed for 650 feet in depth; the ore shoot is 1,200 feet long and carries from 2.9 to 3.3 per cent. copper, with 6 to 14.5 oz. silver, and 0.2 to 1.2 oz. gold per ton.

There is a second group of copper deposits in the north-east part of Cerro de Famatina, known as the Santa Rosa, Encrucijada and Pararrayo. The country is slate, cut by igneous intrusives. The minerals of the Encrucijada veins consist of chalcopyrite, bornite, covellite and chalcocite, containing silver.

The Los Bayos deposits are at a lower elevation (14,000 feet) and carry copper ore in pockets and cavities, in fractures in dacite. The hand-sorted ore is stated to contain up to 7 per cent. copper, but the average is given as 2.75 per cent., with 10 oz. silver per ton.

In other parts of Argentina, copper is worked in the Provinces of Catamarca, Los Andes, Salta, and other places.

In Los Andes, at San Antonio de Los Cobres, veins, ranging from a few inches up to 6 feet in width, occur in conglomerates; the country rock being trachytic and rhyolitic tuffs and agglomerates. The ore of the Concordia mine consists of tetrahedrite, chalcopyrite, galena, zinc-blende, and pyrite; and carries 2 to 4 per cent. of copper, 6 to 7 per cent. of lead, and 30 to 70 oz. of silver per ton. This is sorted up to 4 to 12 per cent. of copper, 20 to 45 per cent. of lead and 100 to 300 oz. of silver per ton.

The Restauradora mine, in the northern part of Capillitas, Catamarca, has over three miles of workings on a vein 1½ to 6 feet in width, in porphyry, the ore consisting of pyrite and chalcopyrite with considerable amounts of chalcocite and bornite. The ores of the district contain a little gold and silver and, usually, galena. Quartz is the principal gangue mineral. According to smelter returns the ores average 7 per cent. of copper with 7 oz. of gold and 8 oz. of silver per ton.

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\* Mineral Deposits of South America, Miller and Singewald. Mines Handbook, Weed.

*Exports of Copper Ore from Argentina.*

(Estadística Minera de la Republica)

Year						Copper Concentrates (long tons)
1913	...	...	...	...	...	305
1914	...	...	...	...	...	—
1915	...	...	...	...	...	66
1916	...	...	...	...	...	228
1917	...	...	...	...	...	—
1918	...	...	...	...	...	152
1919	...	...	...	...	...	—

**Bolivia\***

Copper ores, in which copper occurs chiefly as metal, are found on the Bolivian plateau, between the eastern and western Cordilleras. They occur in a thick belt of porous shales, sandstones and conglomerates, extending from a few miles north of of Corocoro (south-east of Lake Titicaca) to San Bartolo, in the desert of Atacama, in Chile.

The deposits of Corocoro are the best known. The principal ones are situated on a broken anticline, in two series of beds, one series dipping west and the other dipping east, separated by a large fault fissure known as the Dorado vein. Some of the beds carry from 23 to 26 feet of homogeneous ore, averaging about  $3\frac{1}{2}$  per cent. copper over 33 feet of workable thickness. The general average of the beds is from 2 to 3 per cent. of copper.

The Dorado vein, which extends for over a mile in length and nearly  $\frac{1}{2}$  mile in width, and contained ore-bodies yielding sulphides and arsenides of copper, at one time yielded a large quantity of ore but is now practically worked out. The deposit, in depth, contains native copper in leaves, plates, threads, and arborescent and flat masses (often weighing several hundred pounds), as in the Lake Superior district, with a little native silver, malachite, cuprite and azurite. In the beds dipping east the ore is entirely native copper; but in those dipping west the ore near the surface is chiefly chalcocite, associated with arsenides and sulphides of copper.

The Corocoro United Company has three mills each with a daily capacity of from 70 to 100 tons of ore. The native-copper concentrate, or "barilla," containing about 85 per cent. of copper, is shipped to Europe for refining. The chalcocite ore assays about 10 per cent. of copper and is sorted to 18 per cent. to 20 per cent. for export. The ore rejected in sorting, assaying 7 per cent. copper, is treated by the flotation process, yielding a concentrate containing 50 per cent. of copper, which is shipped either to New York or Liverpool.

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\* Comercio Especial de Bolivia. Mineral Deposits of South America, Miller and Singewald.



The production of the company in 1913 was equivalent to 1,689 tons of fine copper. During 1917-18, 169,561 tons of ore averaging 3.83 per cent. copper were mined from which 118,209 tons of sorted ore, containing 5.49 per cent. of copper, were obtained. The total output was 6,389 tons of copper, the increase being due to the advent of the railway.

The Compañía Corocoro de Bolivia is the owner of the largest copper mine in Bolivia, which is developed by shafts and has reached a depth of about 1,740 feet. The ore is native copper and, rarely, silver with some cuprite and chalcocite. It is so soft that it disintegrates in the hand.

The mill capacity is 200 to 250 tons of ore per day, assaying 2 to 3 per cent. copper. Hand-sorted chalcocite, containing 18 per cent. copper, is exported at the rate of 1,500 tons monthly.

Copper-bearing sandstones are worked at Chacarilla, 50 miles south of Corocoro, and in the Galvarino mine at Cobrizos.

The Aramayo Francke mines yield tin, bismuth, wolfram, copper and silver, and comprise several distinct groups at Choro-lque, Santa Barbara and Churquini. During the period 1913-17 the company produced 590 tons of copper matte.

### *Exports of Copper from Bolivia*

(long tons)

(Comercio Especial de Bolivia, Annual)

—	1914	1915	1916	1917	1918	1919
Copper concentrates...	3,812	5,774	5,068	4,854	3,872	2,798
Ingot and matte ...	—	—	—	303	131	86
Sulphide ...	—	—	—	—	1,869	9,913
Precipitate ...	—	—	—	67	132	83
Ore (hand-picked) ...	4,717	17,657	23,477	31,619	19,577	9,717

### **Chile**

Between 1870 and 1882 Chile supplied the bulk of the copper produced in the world. Afterwards the production declined considerably until about 1900 when a revival set in. The development of copper properties, near Rancagua and Chuquicamata, has shown the possibility of working the country's low-grade copper deposits profitably, with a consequent enormous increase in output.

Copper ores are found throughout the greater part of Chile, but most mining has been done in the western range, which is separated longitudinally from the high Andes by the central valley of Chile. The country is built up of an immense variety of sedimentary and igneous rocks and presents great variations in climate, from a rainless belt to one of excessive rainfall, and from tropical heat to arctic cold. The chief copper-producing provinces

are north of lat.  $35^{\circ}$  south, *i.e.*, Antofagasta, Atacama, Coquimbo, Aconcagua, Santiago and O'Higgins, but copper ores have also been reported in the southern provinces.

The distinguishing characteristics of the copper deposits of Chile are the depth of the oxidized zone, and the variety of minerals found in large quantities, including brochantite, atacamite, chalcantite, malachite, azurite, chrysocolla, cuprite and native copper. In the Dulcinea mine, 45 miles north-east of Copiapo, oxidized ores are found 1,500 feet from surface. The enriched sulphide zone, containing mixed oxidized and sulphide ores, is likewise unusually deep, extending in places for several hundred feet and carrying veins or disseminations of chalcocite and bornite, etc. The primary sulphides are reached in northern Chile at an average depth of 1,200 feet or more, and are chiefly chalcopyrite and enargite. The payability of the primary ores is not yet established.

*Province of Antofagasta.*—The most important mines in Chile at the present time are situated in the Department of El Loa in this province, and other important deposits of copper occur in the departments of Tocopilla, Antofagasta and Taltal.

The Chuquicamata deposits, belonging to the Chile Copper Company, are the most extensive of any so far proved in any part of the world. They are situated about 14 miles north-east of Calama and about  $5\frac{1}{2}$  miles from the Antofagasta and Bolivia Railway, and are found on a hill some  $2\frac{1}{2}$  miles long and one-third of a mile in width, which rises to a height of 9,890 feet above sea level. The country is arid and desolate. On the east side of this hill, wide fracture zones, 30 feet in width and containing rich copper-ore, are found traversing the country rock. The remainder of the hill consists of rock which has been greatly shattered, and is so thoroughly mineralized that the entire mass is regarded as ore. The ore obtained from the vein mines is sorted or roughly concentrated with hand jigs and sent to the smelter at Calama.

The hill is honeycombed with old workings, but the Indians only worked upon rich streaks of the veins which are much richer than the shattered ore. The outcrop of these latter deposits is 8,000 feet long with an average width of 554 feet. As a result of drilling it is estimated that the Chuquicamata deposit contains about 700 million tons of copper ore averaging 2.12 per cent. copper. The mines are worked open-cast, in benches, after removal of the overburden.

The oxidized ores contain brochantite with a little atacamite and cuprite, whilst the sulphide ores chiefly consist of chalcopyrite with smaller quantities of enargite and chalcocite. The oxidized and sulphide ores are often found together.

The ore, after crushing to  $\frac{3}{8}$ -inch size, is leached with an 8 to 9 per cent. solution of sulphuric acid in mastic-lined concrete tanks 110 feet by 150 feet by  $17\frac{1}{2}$  feet deep, each of 10,000 tons of ore capacity. The copper is precipitated electrolytically from the solution. The capacity of the works was increased in 1919

to about 13,500 tons of ore per day, equivalent to an annual production of about 67,000 tons of refined copper.

The reserves of Chuquicamata at the end of 1919 were estimated as follows:—

	Tons.	Copper per cent.
Oxidized ore .....	297,813,272	averaging 1·91
Mixed ore .....	134,821,428	„ 2·98
Sulphide ore .....	187,500,000	„ 1·84
	620,134,700	„ 2·12

The extraction in the leaching plant, largely owing to finer grinding of the ore, has improved from 82·2 per cent. in 1916 to 86 per cent. in 1919. The total cost of copper for the year 1919 amounted to 18·35 cents per lb., the cost at the plant being 9·29 cents per lb. The following table shows the progress of this mine since it began production:—

*Chile Copper Company*

Production	1915*	1916	1917	1918	1919
Ore treated (tons) ... ..	558,387	1,556,025	2,593,027	3,343,824	2,644,165
Copper in ore treated (per cent.).	1·71	1·74	1·76	1·64	1·62
Refined copper produced (tons).	4,886	18,440	39,451	45,596	34,249
Recovery of copper (per cent.).	66·87	77·15	81·80	82·20	86·0
Costs in cents per lb. of copper—					
Mining and treatment (costs at plant).		11·75	11·56	10·22	9·29
Depreciation ... ..		3·48	1·75	1·75	2·94
Amortization ... ..		2·94	2·53	2·51	2·40
Other charges, including freights and selling.		3·71	5·41	3·08	3·72
Total costs ... ..		21·88	21·23	17·56	18·35

\* 7½ months.

West of Chuquicamata, there are various copper mines in ancient crystalline rocks, extending along the coast between Tocopilla and Antofagasta. The best known are the Toldo mine at Gatico, 30 miles south of Tocopilla, where there is also a smelting and converting plant. The ore occurs in quartz veins, about 4 feet wide, in granite and consists principally of brochantite and chalcopyrite. The annual production of this mine varied from 1,384 tons to 3,571 tons of copper between 1907 and 1916.

Other copper mines are found in Central Chile near Conchi and San Pedro, both north of Chuquicamata. At San Pedro native copper is found impregnating sandstones as at Corocoro, Bolivia. Copper deposits are also known to exist in other parts

of the province farther south and elsewhere, extending along a line between the ports of Taltal and El Cobre.

*Province of Tarapaca.*—Tarapaca lies between Tacna and Antofagasta, and there are a number of copper deposits in the mountains along the coast and in the high Cordillera.

The principal mines so far developed are in the Collahuasi district. They lie in a mineralized area consisting of volcanic rocks, lavas and tuffs of andesite, diorite and dacite, with intrusions of dolerite and gabbro; and the ore deposits occur in lenticular masses in the andesite. The lenses reach 100 feet in length and 50 feet in thickness, and contain oxidized ores to a depth of 250 feet followed by a thick zone of secondary sulphide ores. Chrysocolla, bornite, chalcopyrite and cuprite are the most common copper minerals, chalcopyrite, brochantite, melaconite, atacamite, tetrahedrite, carbonates and native copper also occur.

The Poderosa group of mines lies at an elevation of some 15,400 feet. The main vein does not appear at the surface but lies under and along a diorite dyke. It has numerous branches and parallel fissures, and is faulted and thrown horizontally in three places from 50 to 100 feet. The ore-shoots in the vein carry from 8 to 60 per cent. copper, and 6 to 8 oz. silver. The mine has been developed to over 720 feet in depth, and the ore-reserves, in 1918, were estimated at 8,000 tons averaging 22 per cent. copper, and 5,000 tons of milling ore averaging 5 per cent. In 1916, 3,948 tons of ore and concentrates averaging 28·7 per cent. of copper with 9·4 oz. silver per ton were shipped; in 1917, 6,980 tons averaging 31·55 per cent. copper and 13·09 oz. silver per ton; and in 1918, 3,309 tons averaging 30·7 per cent. copper and 12·45 oz. silver.

At the Collahuasi Grande mine the ores and mode of occurrence are similar to the Poderosa but, in addition to copper, the ore contains an average of over 5 dwt. of gold per ton.

An interesting deposit occurs at Huiniquitipa some six miles south of Collahuasi and some 2,000 feet lower in altitude. The copper mineral is chrysocolla and occurs as the cementing material in a bed of conglomerate that outcrops on both sides of a low hill. It is reported that 3 million tons containing 3 per cent. copper have been proved by shafts sunk through the bed at numerous points.

The Copaquira copper deposits lie some 130 miles south-east of Iquique in a rainless desert plateau on the western slope of the Andes, 11,000 feet above sea-level. The mineral occurs chiefly in the form of hydrated copper sulphate disseminated in thin irregular veins in a decomposed porphyry.

*Province of Atacama.*—This province is particularly rich in copper mines, but the remoteness of many of them has caused only the richest ores to be worked, and thousands of tons of ore containing from 8 to 12 per cent. copper are said to have been left in the mines or in dumps as unprofitable, whilst in some cases even 15 per cent. ore is unpayable on account of difficulties of transport.

The chief centre of activity has been in the department of Chañaral, in the Coastal Range, owing to its comparative accessibility to the smelters at Carrizal and Caldera. The chief mining camps of the Coast Range are Salado, Pueblo, Hundido, Las Animas and Los Pozos. The Potrerillos mine, owned by the Andes Copper Mining Company, and the group of Los Pozos, Las Animas, Cerro Negro and others belonging to the Société des Mines et Usines de Cuivre de Chañaral, are located in this district.

In some of the mines at Las Animas, which are in diorite and have reached a depth of 1,800 feet, the oxidized zone extends to 500 feet in depth, below which poorer sulphide ores, mainly chalcopyrite, occur. The ore shipped averages about 7 per cent. of copper.

The copper mines of the Copiapo district were amongst the earliest worked with foreign capital, the Copiapo railway, built in 1852, being the first railway constructed in South America. Many mines have been worked in this belt, some to a great depth.

\*The Potrerillos mine, in the main range of the Andes, lies at an altitude of 10,500 feet, 90 miles from the Port of Chañaral, and is one of the most important in Chile at present. The ore-body occurs in quartz-porphyry, intrusive in limestone, and has been proved by churn-drilling to be about 1,800 feet long, 900 feet wide and 850 feet deep. Over 110 million tons of ore had been proved up to 1918, averaging about 1·4 per cent. copper. The ore-bodies are in fault-zones, which have been extensively brecciated. The Company is erecting a 22,000 kw. steam turbine electric plant at Port Chañaral, whence the current will be transported at 100,000 volts potential, and a 15,000-ton per day concentrator at the mines. It is understood that a combination of leaching and flotation will be adopted as the method of treatment.

The Los Pozos district contains numerous lodes in porphyrite, some of which can be traced for several miles. The Mante Monstruo ore-body is stated to reach 300 feet in thickness, and the gossan, where prospected, contains from 4 to 7 per cent. of copper.

The principal developed properties are those of the Société des Mines et Usines de Cuivre de Chañaral, which has developed Las Animas, Los Pozos, El Manto Verde and other mines to a considerable extent.

The smelter at Chañaral has a capacity of 280 tons of ore per day. The product is blister-copper, averaging 99 to 99½ per cent. copper and containing 1·96 oz. gold and 4·9 oz. silver per ton.

At Pueblo Fundido the most important mines are the Carmen and Tres Gracias. They have been worked to 800 feet in depth and have yielded a large quantity of 12 per cent. copper ore. The country rock is mainly syenite. The Carmen lode averages

15 feet in width. The oxidized ores contain much limonite and are used extensively as a flux.

The districts of Punta del Cobre and Amolanas are also important. Amolanas lies about 15 miles south-east of San Antonio and the ores contain much atacamite, cuprite and chalcocite.

Many of the abandoned mines of Copiapo are believed to contain large reserves of low-grade copper ores.

In the northern part of the department of Freirina, in the neighbourhood of Carrizal Alto, many mines, now idle, have been worked, some of them to a depth of more than 1,000 feet. At the Socovon mine, 15 miles from Peña Blanca, the ores averaged 18 per cent. of copper and the vein was 6 feet wide, in granite.

Smelting plants belonging to the Société de Minas y Fundicion de Carrizal are located at Caldera and Carrizal. The Caldera plant treats 5,000 to 7,000 tons of charge per month, mainly purchased, and ships 400 to 600 tons a month of blister copper to Tacoma, Washington, for refining. The Carrizal plant treats from 1,300 to 1,800 tons of charge per month, chiefly from the Astillas mine belonging to the company, and ships about 300 tons of matte per month to Tacoma. Owing to the low price of copper, work was practically suspended in the Caldera and Carrizal districts in the early part of 1919, but was subsequently resumed.

*Province of Coquimbo.*—Numerous copper mines are being worked on a small scale along the line of the longitudinal railway, but lack of capital has retarded the growth of the mining industry in this province. The mines around La Higuera, in the department of La Serena, have been extensively worked, the ores occurring in well-defined veins cutting metamorphic rocks. Some of the mines are over 1,000 feet in depth, and the smelting ore of the district contains from 10 to 18 per cent. of copper.

The Brillador mine, a few miles north-east of La Serena, was worked to a depth of 1,650 feet, and was a large producer.

The department of Ovalle contains, perhaps, the most important mines in the province of Coquimbo, the chief centres being Panulcillo, Tamaya and Punitaqui.

The main lode at Tamaya contains bunches of high-grade ore in a quartz-calcite gangue and was 20 feet wide in one place, yielding ore assaying from 30 to 35 per cent. of copper. The ores carry specular hæmatite, bornite and chalcopyrite, with chalcopyrite alone below 500 feet.

In the Panulcillo district, the Central Chile Copper Company is working mines 15 miles north-east of Ovalle, and near Nisfile. The Panulcillo group comprises the Panulcillo Alto and San Gregorio mines, which produce mainly chalcopyrite associated with pyrite in a limestone gangue.

*Province of Aconcagua.*—The copper deposits of this province are of lower grade than those farther north, but in some localities large ore-bodies have been proved. They are numerous in the departments of Petorca, La Ligua and Putaendo, and others are

found in San Filipe and Los Andes. The surface ores of the Catemu Valley carry a good deal of lead and zinc with silver.

The Mantos Rojos mine is in an area of sandstone and limestone, penetrated by eruptives, and comprises two beds, from 5 to 7 feet thick, composed of calcareous matter impregnated with copper minerals. These consist chiefly of bornite, with chalcopyrite and grey copper as accessories. The ore varies from 3 to  $4\frac{1}{2}$  per cent. copper, and is valuable for fluxing purposes. The production in 1918 is stated to have been 5,000 tons per month of ore containing 4 per cent. of copper, and sufficient reserves were developed to suffice for three or four years.

The El Soldado mine, near Nogales, on the Calera-Cabildo Railway, has 15 quartz veins, from 5 to 7 feet in width, containing copper sulphides, and lying on a fault contact between trachyte and felspar-porphyry. The ore is reported to contain from 5 to 6 per cent. copper.

*Province of Santiago.*—Copper ore has been mined in several places in the Cordillera and in the Coastal Mountains east and west of Santiago City, the three chief localities being Las Condes, on a tributary of the Mapocho river; El Volcan, in the valley of the Maipo river; and Naltagua, near the railway station of El Monte, between Santiago and Melipilla.

The Las Condes mine is an extensive deposit somewhat similar to the Braden copper deposits, but situated at an elevation of 12,000 feet, where weather conditions during more than half the year are extremely unfavourable. The volcanic breccia worked is estimated to contain 3 to 4 per cent. copper, chalcopyrite being the cementing material. Only high-grade ores up to 24 per cent. copper are being worked. The district also contains copper-sulphate deposits of a similar nature to those of Copaquire.

The Naltagua deposit is very extensive, showing parallel bedded-veins in limestone and in porphyry. The beds have been opened up for a length of 3 miles, and are said to average 4 per cent. copper at about 65 feet in depth. The San Ramon is the principal producer, the bed averaging  $7\frac{1}{2}$  feet in thickness, carrying oxidized ores down to about 65 feet, succeeded by bornite which disappears in depth, disseminated chalcopyrite taking its place. The ore mined contains from  $1\frac{1}{2}$  to  $4\frac{1}{2}$  per cent. copper, and is self-fluxing. The Ranchos mine contains a bed, 6 feet thick, of 4 per cent. ore in porphyry. The total production of these mines, in 1917-18, was 3,596 tons, in the form of Chile bars assaying 99 per cent. of copper.

The Aguirre mine, 12 miles west of Santiago, belonging to a subsidiary of the Anaconda Copper Company, covers a disseminated ore-body in which 6 million tons of ore have been developed, assaying from  $1\frac{3}{4}$  to  $3\frac{1}{2}$  per cent. of copper in mixed oxides and sulphides. The Africana mine, belonging to the same interests, and 3 miles east of Lo Aguirre, contains a number of veins of high-grade ore assaying from  $4\frac{1}{2}$  to 9 per cent. of copper. Owing to the sulphur content, these ores can be used for the manufacture of sulphuric acid required for leaching the oxidized ores at Lo Aguirre.

*Province of O'Higgins.*—This province contains the Teniente mines of the Braden Copper Company, in the main range of the Andes at an elevation of 8,000 feet, east of Rancagua, and connected with the longitudinal railway by a narrow-gauge line 43 miles long. These deposits, which are second in importance only to those of Chuquicamata, occur in andesite breccia of Tertiary age, surrounding a plug of tuff which fills the crater of an old volcano. They consist of a series of irregular lenses around the circumference of the volcanic neck, where the andesite has been thoroughly broken up and the openings and seams filled by mineral sulphides. Fumaroles are found, around which oxidation has taken place to a considerable depth. The ore in the brecciated andesite varies from a mere film to 3 to 4 inches in thickness and consists chiefly of chalcopyrite, with smaller amounts of bornite and numerous other minerals of copper, zinc, iron and lead. Occasionally native copper is found in the vicinity of the fumaroles.

Five distinct ore-bodies are known, of which four are worked; all being characterized by strong outcrops stained with copper. The Teniente ore-body is the largest, having a length at No. 1 level of 4,800 feet, an average width of 300 feet, and a proved depth of 840 feet. It is also the richest ore-body of any size. The reserves of the mine were estimated, in 1918, at 173½ million tons of positive ore, containing 2.45 per cent. copper, and 90 million tons of probable ore containing 1.88 per cent. copper. Electric power is generated at Coya, on the Cachapoal river. It is intended to duplicate the power plant by a second installation on the Pangal river. Ropeways connect the mine with the mill at Sewell, which is connected by a ropeway with the smelter at Catelones. The mill is designed to handle 10,000 tons of ore per day, and is equipped with crushing, concentration, flotation and acid plants.

The production during the period under review was as follows.—

Year	Ore milled		Blister copper produced	
	Quantity (long tons)		Quantity (long tons)	
1913	...	—	...	8,080
1914	...	803,838	...	12,636
1915	...	987,875	...	14,613
1916	...	1,216,633	...	18,818
1917	...	1,606,869	...	28,470
1918	...	1,752,638	...	34,443
1919	...	—	...	20,982



*Production of Copper in Chile*  
(Statistical Abstract of the Republic of Chile)

Year	Copper (Pig)		Copper Matte		Copper Ores		Total production of Fine Copper (long tons)
	Quantity (long tons)	Copper Content (per cent.)	Quantity (long tons)	Copper Content (per cent.)	Quantity (long tons)	Copper Content (per cent.)	
1913 ...	19,826	98·94	18,213	47·20	71,371	18·73	41,586
1914 ...	24,831	98·99	15,730	47·14	70,724	16·89	43,947
1915 ...	34,234	99·14	16,767	47·54	63,699	15·05	51,500
1916 ...	56,660	99·49	8,496	50·10	55,979	16·98	70,143
1917 ...	84,071	99·53	21,070	48·83	32,905	20·99	100,879
1918 ...	101,282	99·55	6,898	46·03	5,902	21·78	105,196
1919 ...							78,301

### Peru\*

The principal copper deposits of Peru, are essentially silver-copper or copper-silver ores, about nine-tenths of the production being obtained from the Cerro de Pasco and Morococha districts, but in a few localities copper has been won from ores carrying little or no silver.

On the border of the department of Ica, bounding the desert pampas on the east, mines have been opened up at San José de Los Molinos, Canza, Tingue and Nazca, in a belt parallel to a range of hills, formed mainly of diorites, with segregations of basalt and younger quartz-diorite, merging into granite. The veins occur parallel to the line of basalt eruptions and are probably related to the basalt. The ore occurs in shoots and contains most of the oxidized minerals of copper in the upper portions of the veins which only have been worked. The ores contain up to 12 per cent. copper.

In the Toquepala Valley, department of Moquegua, the Vesuvius vein, in granite, is said to be 26 feet wide, and carries a ferruginous quartz gangue, containing chrysocolla, malachite, azurite, cuprite and melaconite. The copper-content is stated to average 11 per cent.

The Cerro de Pasco mine is situated in the department of Junin, in a group of low hills on the pampa between the central and western ranges of the Andes, at an altitude of about 14,000 feet. The rocks in the vicinity are limestones and conglomerates, associated with shales and sandstones of Cretaceous and Mesozoic age, penetrated by numerous igneous intrusions. An intrusion of rhyolite agglomerates and tuffs, about  $1\frac{3}{4}$  miles in diameter, west and north-west of the town of Cerro de Pasco, is surrounded by limestone, and the ore deposits are chiefly found in the agglomerates and tuff, which in places have been intensely sheared.

\* Mineral Deposits of South America, by Miller & Singewald, p. 460. Revista Minera.

The silver-content of the great mass of oxidized argentiferous ore, now nearly worked out, varied greatly, running occasionally up to thousands of ounces per ton, but the copper in the zone of oxidation was almost completely leached out. In the oxidized zone a considerable amount of gold occurred in rich but erratic shoots, yielding as high as 1 to 2 ounces per ton. Below this, there is an enormous mass of low-grade pyritic ore, and at the north end of the deposit, there is a layer of rich copper ore, between the oxidized zone and the pyrite below. Farther south, the principal ore shoot, known as the Piña Blanca, carries a mixture of pyrite, with enargite and famatinite, and consists in places almost entirely of copper minerals. Several distinct veins of similar high-grade ore cut the mass of low-grade pyrite.

The sulphide ore bodies of Cerro de Pasco are considered to be replacement stocks in a country rock of rhyolite agglomerate and tuff. On the west side of the sulphide stocks, the country is traversed by a series of cross veins, the principal ones, lying west of the south end of the Piña Blanca shoot, being known as the Cleopatra, Docena, Bolognesi and San Ancelmo. The vein-filling is quartz with pyrite, enargite and famatinite, a considerable amount of tetrahedrite and some chalcopyrite. These veins average 5 feet in width and contain rich pockets and shoots of ore, but the copper minerals are sufficiently well distributed to render them workable through practically their entire extent. In the early days, the copper sulphide ores were only worked to supply the copper sulphate needed for the *patio* process; but matte-smelting was commenced in 1897. Ores above 30 per cent. copper were exported to Europe, or sold to the Yauli and Casapalca smelters, and those of lower grade were reduced to matte for exportation, until the properties were taken over by the Cerro de Pasco Copper Corporation, which commenced smelting to blister copper in 1906. The monthly output of the Cerro de Pasco mines is over 30,000 tons of ore, the first-grade ore containing 8 to 10 per cent. of copper with appreciable amounts of gold and silver. The average grade of the ore from the district is about 11 ounces silver per ton and 7 per cent. copper, and the blister copper produced is stated to carry 140 ounces silver and 1 ounce of gold per ton. All the ores are refractory owing to the presence of bismuth and contain from 14 to 30 per cent. iron, and 35 per cent. of silica. The smelter at La Fundicion is provided with a sampling mill, and does a small amount of custom work. The works are terraced and comprise five blast-furnaces of about 300 tons daily capacity each, and basic-lined converters, which produce 99 per cent. blister copper which is refined at Baltimore, U.S.A. It is proposed to erect a new smelter near Oroya Junction, at 2,000 feet lower altitude, and nearer to the Morococha mines belonging to the same Company.

The Cerro de Pasco Copper Corporation also owns extensive coal mines and other interests in Peru. The cost of production may be estimated at 8 cents per lb. of copper and the annual output is about 31,000 tons. Ore reserves are stated to be 4 years ahead of smelter consumption.

Morococha, like Cerro de Pasco, is one of the old mining districts of Peru and in the early days furnished rich silver-lead ores with some gold. It lies on the east side of the western Cordillera in the department of Junin, in a valley running approximately east and west. The monthly production of the district has now reached 20,000 tons of ore averaging about 12 ounces silver per ton and about 10 per cent. copper. Under favourable conditions 5 to 6 per cent. copper ores can be worked at a profit. The rocks of the district consist of a thick series of limestones and quartzites, of Mesozoic and Cretaceous age, intruded by porphyry and peridotite. The most important veins are in the porphyry which, at the contact of the porphyry and peridotite, forms flat-lying masses of considerable extent. The filling of the veins consists of quartz, pyrite, enargite and tetrahedrite, with zinc-blende occasionally. The San Francisco mine is the most important producer in the district and belongs to this type of deposit. Replacement veins also occur in certain beds, in the limestone, with local enlargements that may be repeated at several horizons. The ore in such cases, as in the Ombla mine, is characterized by the predominance of chalcopyrite with some bornite. The principal vein-filling material consists of quartz and pyrite, with some zinc-blende and galena. Sulphantimonides, which are found abundantly in the veins in porphyry, are almost completely absent. The principal mines, which belong to the Cerro de Pasco Copper Corporation and the Sociedad Minera Backus y Johnston, lie between Huacracocha and Morococha lakes.

The San Francisco mine, belonging to the Cerro de Pasco Copper Corporation, has a production of 9,800 tons of copper annually. In the Mina Gertrudis, belonging to the same Corporation, three limestone beds, with ore impregnations following the bedding planes, are being worked. A rich streak, from 24 to 40 inches wide, contains grey copper and chalcopyrite and averages about 14 per cent. copper and 35 oz. silver per ton; the remainder of the vein, from 40 to 55 inches, contains 5 per cent. copper and 10½ oz. of silver per ton.

Another important group of mines in this district comprises the Natividad, Churruca, Ombla, La Vieja, Santa Clara and others. The Natividad is the deepest shaft in the district being over 1,000 feet deep. The ore produced by this group amounts to about 4,000 tons a month, averaging about 2 per cent. copper and 40 oz. silver per ton, and is carried over the Peruvian Central Railway to the smelter at Casapalca, 19 miles distant from the mines.

The mines of the Casapalca district are situated on the Cerro Casapalca, at altitudes ranging from 13,600 to over 17,000 feet.

The Carlos Francisco mine has a monthly production of 6,000 tons of ore averaging 25 to 30 oz. silver per ton and 1½ to 1½ per cent. copper. The crude ore is concentrated in a mill of 200 tons daily capacity, adjoining the Casapalca smelter, and producing 2,500 to 3,000 tons of selected ore and concentrates averaging 2 per cent. of copper, 5 per cent. lead, 13 per cent. zinc

and 40 oz. of silver per ton. The principal vein averages about  $2\frac{1}{2}$  feet in width and can be followed for over a mile in andesite, passing into limestone at each end. The workings extend along a length of 7,500 feet and the vein has been proved to a depth of over 2,500 feet below outcrop. The vein-filling consists of quartz and pyrite, with tetrahedrite and some chalcopyrite as the valuable constituent. Galena and zinc-blende are sometimes found. The ratio of silver to copper decreases with depth, from 1 : 20 in the upper levels to 1 : 30 in the lower workings.

In the Cerro Verde mine (a subsidiary of the Anaconda Copper Company), 20 miles south-east of Arequipa, copper occurs disseminated in rhyolite near the contact with porphyritic diorite. The rhyolite is divided by two irregular masses of granodiorite. The oxidized zone extends for about 220 feet in depth, and carries silicates and carbonates, passing into secondary sulphides which at a lower depth give place to primary sulphides. It is estimated that the deposit contains more than 10 million tons of ore averaging from 2 to  $2\frac{1}{2}$  per cent. copper.

The Ferrobamba group of mines is situated about 45 miles west of Cuzco, at an elevation of some 13,000 feet above sea-level. The deposit is of the contact metamorphic type in a garnet rock at the junction of limestone and granite. In Ferrobamba No. 1 an area of 84 acres is estimated to contain approximately 12 million tons of payable ore, to a depth of 200 feet; and up to 1912 6 million tons of ore, averaging 3.7 per cent. copper and 1.3 per cent. sulphur, are stated to have been proved by churn-drilling and underground workings.

The Charcas group in the same district is reported to contain an ore-body 328 feet wide and 2,625 feet long, containing chalcopyrite and pyrite, a surface exposure assaying 3 per cent. copper, 3 oz. silver and  $5\frac{3}{4}$  dwt. gold per ton.

At Yauricocha, in the district of Yauyos, on the western slope of the Andes, 50 miles south-west of Pachacayo on the Peruvian Central Railway, a deposit of copper ore occurs at a contact between limestone and diorite. The ore consists of carbonates down to water-level, which is from 400 to 500 feet below the surface. The ore is reported to average 12 per cent. copper, 3 oz. silver and 2 dwt. gold per ton, and the vein is said to be proved for 2,500 feet in length and some 400 feet in depth.

In northern Peru copper ore has been mined and smelted at Sayapullo and Conchucos.

At Sayapullo, in the province of Cajabamba, and about 40 miles east of Huabal on the Trujillo railway, numerous veins occur in limestones, sandstones and shales in the vicinity of trachyte intrusions. The minerals are argentite, tetrahedrite, enargite, chalcopyrite and pyrite in a quartz gangue, the veins varying in width from 15 inches to over 20 feet.

At the Magistral mine, Conchucos, in the province of Pallasca, important quantities of silver were originally produced. It is now worked for copper values which occur as chalcopyrite in pyrite, in mineralized zones, up to 100 feet wide, in limestones intruded by andesite.

*Production of Copper in Peru (long tons)*  
(Estadística Minera del Peru, Annual)

Year	Copper contained in						Total Copper Content
	Bars	Matte	Ore	Precipitate	Silver Sulphides	Other Products	
1913	20,041	4,360	2,902	16	10	1	27,330
1914	24,372	651	1,605	17	10	—	26,655
1915	32,070	759	1,266	60	14	—	34,169
1916	39,780	864	1,693	39	10	—	42,386
1917	42,421	460	1,556	4	9	—	44,450
1918	43,136	137	380	30	10	7	43,700
1919	37,547	295	531	1	6	220	38,600

*Exports of Copper Bars from Peru*

(Statistical Abstract of Peru, 1919)

Year	Quantity (long tons)			
1914	...	...	...	19,760
1915	...	...	...	32,474
1916	...	...	...	41,130
1917	...	...	...	41,653
1918	...	...	...	43,540
1919	...	...	...	40,246

### Venezuela

The northern mountain ranges, which form spurs of the Colombian Andes, are reported to contain copper in many places, but the only district in which copper mines have been actively worked in recent years is in the Aroa region in the State of Yaracuy, about 67 miles west of Puerto Caballo, at an elevation of 1,165 feet above sea-level. The region consists of slates and limestones, intersected by dykes of igneous rock, and the ore is found in irregular lenticular bodies in the slates. The upper levels carried rich oxidized ores, consisting of malachite, azurite, melacoenite and cuprite, but these have been mostly exhausted, and gave place to chalcopyrite and pyrite in depth.

The vein at the Aroa mine was from 50 to 75 feet in width at surface, and was exposed for over 2,000 feet. The best-grade sulphide ore, containing 9 per cent. of copper, is shipped to Great Britain; the low-grade ores, mixed with oxides, are smelted at the mine to copper matte. In 1916, the South American Copper Syndicate, Ltd., which also owns the San Antonio and Titiaira mines, shipped 5,000 tons of crude ore, in addition to a quantity of matte.

*Production of Copper Ore in Venezuela*

(Bulletin of the Pan-American Union)

Year		Quantity (long tons)	Copper Content* (long tons)
1914†	...	5,116	358
1915†	...	8,401	588
1916†	...	16,510	1,156
1917	...	41,591	2,911
1918	...	29,231	2,046
1919	...	2,647	185

**Turkey (Asiatic)**

The copper ore resources of Asia Minor have been described by G. M. Edwards.‡ Copper ore can be found almost anywhere in the northern provinces. The country inland for the whole distance from the Bosphorus to Batum is copper-bearing. The number of old workings is very large. In general, the veins are narrow and rich, containing 20 per cent. or more of copper, but there are many exceptions to this rule, these including the Aghana mine and the so-called copper "basin" of Hendek.

The Aghana mine (Aghana Maaden) is situated in the centre of Asia Minor, about 250 miles to the north-east of Alexandretta, and about 40 miles north-west of Diarbekr, on the Tigris. The mine is owned and worked by the State, and has for many years been the chief copper producer in the Ottoman Empire. Its situation is unfavourable for economic exploitation, but in 1912 the Government derived a revenue of £66,000 from the mine, of which £26,000 was profit. During the period 1897-1912 the lowest production was 454 tons of "black copper" (*i.e.*, impure metallic copper produced by smelting oxide ores or roasted sulphide ores in the blast-furnace) in 1897, and the highest production 1,800 tons in 1912. The deposit is found on the top of a low plateau several hundred feet above the surrounding country. The region consists of basic igneous rocks, and the mine itself is in a broad belt of serpentine (peridotite) which traverses them. The actual deposit is oval in shape, nearly 700 feet in proved length, and 400 feet in maximum width. The ore-body appears to persist beyond the ends of the present workings, but the miners prefer to work in the wider portions of the deposit. The greatest depth reached in 1913 was 80 feet, the length and width of the deposit being maintained. The deposit consists of massive iron-pyrites and chalcopyrite, without gangue. Large masses of pure chalcopyrite occur free from iron-pyrites, and most of the

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\* Estimated at 7 per cent.

† Exports. Figures for 1914 are for six months only.

‡ Notes on Mines in the Ottoman Empire; Trans. Inst. Min. Met., 1913-14, 23, 192-210.

work is concentrated on these. The ore in general contains 8 per cent. copper, but the masses of chalcopyrite bring the average up to 15 per cent. Ore containing less than 10 per cent. copper is not worked. The ore-body is exploited by numerous adits and spiral inclines, the mine being worked on a tribute system, the miners selling their copper matte to the Government at a price equivalent to about £16 per ton. The ore is carefully picked, afterwards roasted in heaps, and then smelted in small cupolas to a matte averaging 65 per cent. copper. This product is shipped to Germany from Alexandretta. In 1913 it was officially estimated that there were still 700,000 tons of ore in the mine averaging 10 per cent. copper.

In the neighbourhood of the Aghana mine outcrops of other deposits of copper ore occur.

The Hendek copper "basin" deposit is situated less than 80 miles from Constantinople, and about 20 miles from the railway station of Ada-Bazar, on the Bagdad railway. The copper ore is found here impregnating beds of schist, resembling greatly the Mansfield deposits of Germany. The small amount of work done has indicated that these beds are on the average thicker and richer than those of Mansfield. Prospecting has disclosed the existence of five separate impregnated horizons. The district is covered by 26 concessions and has an area of about 80 square miles. The cupriferous series has a uniform dip of 30°, the thickness of the impregnated beds varying from 12 inches to 7 feet, and averaging 2½ feet. Numerous assays indicate an average copper-content of 5 per cent., one report giving the average as 7 per cent.

There is an old copper-mining region at Küre, about 12½ miles from Ineboli, on the Black Sea coast.

Beyschlag mentions a copper mine in the west part of the Caucasus, then recently assigned to Turkey (the region from Batum to Kars), at Khvarzkhana, near Artvin, south of Batum. Before the war this mine was equipped by the Siemens family with a smelting works having a capacity of 2,000 tons of copper per annum, but the plant does not appear to have been operated up to the present time. At Dzansul, in the same region, an American company owns a copper mine and a smelter, which produced 3,030 tons of copper in 1912 and 4,000 tons in 1914.

### China\*

The occurrences of copper ore in China are extremely numerous, but few have been proved to be of value. The principal deposits are in the provinces of Yunnan, Szechuan, Anhui and Kansu. According to their origin, these deposits have

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\* Mineral Resources of China, by V. K. Ting; Special China Supplement North China Daily News, 1917. Mining Mag., 1917, October, p. 189, also 1920, Nov. and Dec., pp. 267 and 331. Trade Reports of the Maritime Customs. The Chinese Year Book.

been classified in five groups: (1) magmatic segregations, (2) contact deposits, (3) replacement and fissure veins, (4) impregnations, and (5) sedimentary deposits. So far as is at present known the first two groups are of no economic importance. Group (3) is by far the most important, the famous copper mines of Tung-chuan, in Yunnan, being of this character. The ore is of high grade, usually above 8 per cent. copper, and the possible reserves are large. The deposits in the limestone are formed by replacement, while in shaly rocks they are fissure veins. Similar deposits occur in the Hueili district of Szechuan. Group (4) is found exclusively in the pre-Cambrian crystalline rocks of south Shansi and north-west Hupeh. They are usually of low grade, but the reserves are sometimes considerable. The Government mine of Peng-shien, near Chengtu, in Szechuan, is on a deposit of the same nature. There, the ore-bodies are large lenses in the crystalline schists and limestone, the copper content averaging about 5 per cent. Group (5) is of great geological interest. In Yunnan and Kweichow the Lower Triassic sandstones, overlying the Permo-Triassic coal measures, always contain some copper, usually in the form of malachite, which was formerly worked extensively in Tantang, in the district of Hsuanhui, Yunnan. Similar deposits occur in the Hanhai formation in Turkestan, an example being the copper mines near Aksu.

The mines of Yunnan are said to have been producing copper for a thousand years, and are credited with having had an annual production, at one time, of 9,000 tons of metal. This was employed in coinage and the whole industry has, in consequence, always been under close Government supervision and has been considerably restricted thereby. The ores consist of alteration products from copper pyrites, chiefly carbonates, which are sorted to a grade containing 20 per cent. copper, the minimum accepted by the smelters. The smelting arrangements are very crude in most cases but one mine has been worked by Japanese on European lines.

At Yaokai, in Kansu, there is a modern smelting plant, belonging to the Chinese Government, which smelts the ores of the province.

The present annual production of copper in China is said to be about 2,000 tons, this being obtained mostly from Yunnan, Kirin, Kansu, and Turkestan, Yunnan supplying about one-half. The production has declined in recent years owing to the exhaustion of the mines to depths available for primitive methods of working, the exhaustion of timber for smelting purposes and the burdens placed on the industry by the Government.



*Imports of Copper into China*

(Trade Reports of the Chinese Maritime Customs, Annual)

Year			Ingots and Slabs	Bars, Rods, Sheets, Plates, Nails and Wire
			(long tons)	(long tons)
1913	...	...	11,951	857
1914	...	...	15,710	1,832
1915	...	...	2,058	623
1916	...	...	1,551	578
1917	...	...	1,656	635
1918	...	...	7,357	631
1919	...	...	18,934	2,377

*Exports of Copper Ingots and Slabs from China*

(Trade Reports of the Chinese Maritime Customs, Annual)

To	Quantity (long tons)						
	1913	1914	1915	1916	1917	1918	1919
Total to British Possessions*	—	17	3	—	—	—	1
Japan and Korea (including Formosa).	61	16	2,675	33,595	41,054	2,661	543
Other Foreign Countries ...	63	76	5	24	6	—	1
Total to Foreign Countries...	124	92	2,680	33,619	41,060	2,661	544
TOTAL ...	124	109	2,683	33,619	41,060	2,661	545

\* Chiefly to United Kingdom.

**Formosa (Taiwan)\***

The Kinkwaseki mine, in the north-eastern part of the island and about 10 miles east of the harbour of Keelung, is the principal copper producer of Formosa.

The oxidized portions of the deposit were worked as a gold ore but below this enargite occurs in stockworks in sandstone and dacite. The ore averages 4·2 per cent. copper and 10·4 dwt. gold and 6·45 dwt. silver per ton.

\* Mining Industry in Japan, Imp. Bur. Mines, Tokyo.

*Production of Gold and Copper Ore in Formosa*

(Statistical Reports of the Department of Agriculture and Commerce, Japan. Annual)

Year	Gold and Copper Ore			Copper content
	Quantity (long tons)			Quantity (long tons)
1913	...	...	...	28,892
1914	...	...	...	35,811
1915	...	...	...	42,883
1916	...	...	...	26,532
1917	...	...	...	14,876
1918	...	...	...	6,155
1919	...	...	...	...

**Japan\***

Japan has for several years been the second largest producer of copper in the world, ranking next in importance to the United States, but in 1918 was displaced by Chile. The principal mines include the Ashio, Kosaka, Besshi and Hitachi (all situated in Honshu) each of which has produced more than 10,000 tons of copper in one year. In addition to the mines named, there are many more of importance. Until recently, from one-half to two-thirds of the output was ordinarily exported, but in May, 1919, Japan became a heavy importer of the metal, buying nearly 40 per cent. of the copper exported from the United States in that year. This is understood to have been due partly to requirements for very extensive hydro-electric installations and partly to increased brass manufactures for China and India. It is reported, however, that the smaller mines of the country were closed down in 1919, while the output of the larger mines was curtailed.

The ore deposits are very widely distributed throughout Japan proper, by far the greater part of the production being obtained in Honshu, while Shikoku and Hokkaido, in the order named, contribute substantial tonnages. There is also a production of copper in Taiwan (or Formosa) and in Chosen (Korea). Nearly half of the copper production is derived from (a) lenticular or bedded deposits of cupreous pyrites, occurring usually in crystalline schists and the Palæozoic formations; and (b) deposits of "black ore" (*kuromono*) occurring near the contact of Tertiary rocks with rhyolite or andesite.

The ore of class (a) is commonly basic and often associated with pyrrhotite, hæmatite or magnetite; while that of class (b) is an intimate mixture of galena, blende and barytes, containing some copper, gold and silver—a highly basic ore, but sometimes

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\* Mining in Japan, Past and Present; Bureau of Agriculture and Commerce of Japan, 1909. Mining Industry in Japan; Imperial Bureau of Mines, Tokyo, 1914. W. H. Weed; The Mines Handbook (Annual).

associated with acidic ores that are suitable as a flux. In addition, a large number of important deposits of copper ore occur as fissure veins in Tertiary rocks. The ore in these veins is siliceous. A third mode of occurrence is as contact-metamorphic deposits, a type found commonly in the Palæozoic formation, and especially abundant near the contact of limestone with granite or allied rocks. The characteristic gangue minerals are pyroxene, amphibole, garnet, epidote, etc. The ore is neutral or self-fluxing.

The copper ores of central Japan, which occur in Tertiary volcanic rocks and consist of chalcopyrite and pyrite, contain from about  $2\frac{1}{2}$  to  $3\frac{1}{2}$  per cent. of copper; while the lenticular deposits of cupreous pyrites mined in the west and south-west of Japan, in the Palæozoic schists, yield smelting ores containing from  $3\frac{1}{2}$  to 4 per cent. of copper, with only a small percentage of silica.

The Fujita Company is successfully working about thirty mines in Japan, Korea and Formosa and owns a number of other copper properties, some of which are being developed. In 1916, the company's production had a value exceeding £1,000,000, the output including 10,107 tons of copper, 1,169,000 oz. of silver and 27,000 oz. of gold, representing about 17 per cent. of the total output of copper in Japan for that year, about 30 per cent. of the total silver and 13 per cent. of the total gold. The company owns the following important copper and pyrite mines: the Kosaka, Hanaoka, Omori, Oarawawa, Matsuoka and Obiye; also smelting and refining works, including the Inushima smelter on the island of Inu, and an electrolytic refinery at Kosaka.

The Kosaka mine, situated at the extreme north of Hondo, is the largest copper mine in the Far East. The country rock, a brecciated porphyry tuff of Tertiary age, is penetrated by intrusions of rhyolite and andesite, and the ore-bodies, five in number, occur along the contact zone between the tuff or rhyolite and andesite. They are of great size, ranging in thickness from 20 to 270 feet, and have been proved for a length of half a mile, whilst drilling has shown their persistence to a depth of 1,700 feet. Three grades of ore are mined: "black ore," a complex sulphide; "yellow ore," the pyritic ore proper; and "siliceous ore," a low-grade ore necessary for smelting. The black ore is an intimate mixture of zinc-blende, galena and barytes, and is extremely basic. It averages 2.43 per cent. copper and contains from 12 to 18 per cent. of zinc, with about 7 oz. of silver and from a trace to 2 dwt. of gold per ton, the gangue containing from 40 to 45 per cent. of barytes. Lead and iron are also present. The pyritic ore averages 2.34 per cent. copper, with 0.47 per cent. lead, 3.15 per cent. zinc and 26.83 per cent. iron. The siliceous ore carries 1.27 per cent. copper, 0.26 per cent. lead, 1.48 per cent. zinc and 19.4 per cent. iron. The ore-reserves of this mine are very large. The Kosaka smelter has a daily capacity of about 1,000 tons, the blister produced being

refined electrolytically. The annual output has been about 12,700 tons of copper, 335 tons of lead, 830,000 oz. silver, 20,000 oz. of gold, and 250 tons of zinc.

The Omori mine is situated in a mountainous region in the Province of Iwami in the north-west of Hondo, near the coast. The ore occurs in veins in a mass of andesite penetrating Tertiary tuffs and sandstone. Five veins are worked, varying in width from 10 inches to 3 feet. The ore occurs in bands averaging 7 inches in width, but running sometimes up to 6 feet. Some of the veins are as much as 2,000 feet in length. The ore consists principally of chalcopryrite, galena and zinc-blende, and averages 6·6 per cent. copper,  $7\frac{1}{2}$  dwt. gold and  $13\frac{1}{2}$  oz. silver per ton. The matte from semi-pyritic smelting is re-smelted by the Mabuki process, producing 98 per cent. blister copper, from which important quantities of gold and silver are obtained by refining. The output of blister copper at Omori in 1914 was 465 tons, in 1915 500 tons, and in 1918 326 tons. The product is treated at the Kosaka electrolytic refinery.

The Oarasawa mine is situated at Yuda-Mura near the Kosaka mine. Many veins, varying in width from 6 inches to 6 feet, traverse granite, tuff and rhyolite of Tertiary age. The ore-minerals are chalcopryrite, iron-pyrites, and oxides of copper, in a gangue consisting chiefly of quartz. The Unekura mine is 5 miles west of the Oarasawa and is worked in conjunction with it. The ore mined is mechanically dressed to 7·5 per cent. grade. The annual production at these mines, including a small quantity of purchased ores, is about 1,650 tons of blister, containing 98 per cent. copper, with  $2\frac{1}{2}$  dwt. gold and  $13\frac{1}{2}$  oz. silver per ton, which is sent to the Kosaka electrolytic refinery.

The Matsuoka mine, situated three miles west of Yuzawa railway station, in Iwate prefecture, has been worked since the 18th century. The deposit is a network of veins in rhyolite and tuff of Tertiary age containing chalcopryrite, galena and zinc-blende, and assaying 0·95 per cent. copper with 1·6 dwt. gold and  $2\frac{1}{4}$  oz. silver per ton. This is dressed to 2·3 per cent. copper, 1 oz. 12 dwt. gold per ton and 4 oz. silver per ton. The production of dressed ore in 1916 amounted to 15,000 tons.

The Hanaoka mine, in Akita prefecture, consists of lenses of massive copper-pyrites, galena, zinc-blende and gypsum. After hand-picking the ore is transported to the Kosaka smelter, 18 miles distant. The production of the mine in 1918 was 125,582 tons, containing 3·1 per cent. copper, and  $\frac{1}{2}$  dwt. gold, and 1 oz. 7 dwt. silver per ton.

The Inushima copper smelter, on the island of Inu, treats both Japanese and Korean ores. Semi-pyritic smelting is employed. The smelting capacity is about 7,000 tons of ore and 280 tons of blister copper per month, about half of which goes to the Kosaka refinery. The production of blister in 1916 amounted to 3,330 tons.

In addition to the above mines, the Fujita Company also owns the Kobayaku, Kawamata and other mines with a total annual

production of about 40,000 tons of ore, containing from  $2\frac{1}{2}$  to  $6\frac{1}{2}$  per cent. of copper.

The Furukawa Mining Company owns 25 mines and 4 copper works in Japan, and is a most important enterprise, with an annual production of 35,000 tons of copper, 20,000 tons of copper wire and plate, 1,200,000 tons of coal, and large quantities of gold and silver bullion, pig lead, zinc, etc. The company operates the Mizushima smelter near Tamashima, the Amagasaki refinery near Osaka, the Nikko copper works, and the Honjo copper works, Tokyo. The copper mines worked by this company include the Ashio, Ani, Furokura, Mizusawa, Kusakura, Hirotani, Nagamatsu, Kune, and many others.

The Ashio mines are about 100 miles north of Tokyo and 18 miles west of Nikko, the group including the Honzan, Kotaki, and Tsudo, which are distant three miles from each other. The ore deposits occur in veins which mostly traverse a volcanic neck of Tertiary rhyolite two miles in diameter erupted through Palæozoic slates, quartzites and limestones. There are more than 200 veins which form two vein systems intersecting one another in a network. They range in width from 1 to 16 feet, and in length from 400 to 6,000 feet. The chief ore minerals in the sulphide zone are chalcopyrite and pyrite, but zinc-blende, arsenopyrite, galena and pyrrhotite frequently occur. Bornite is the principal copper mineral down to 400 feet below adit level, but chalcocite, cuprite, malachite, and sometimes native copper and azurite are also found. The gangue consists chiefly of quartz, calcite also occurring, and sometimes gypsum.

The daily production of copper ore is 250 tons, containing 12 per cent. copper, and 1,500 tons containing 0.75 per cent. About 12,000 tons of copper are produced annually from the mine. The three mines communicate with each other by shafts and levels. There are three main adits. The vertical depth of the underground workings from the highest outcrop to the Tsudo adit is 2,200 feet, and from that level 1,500 feet, making a total depth of 3,700 feet. The aggregate length of drifts is about 190 miles. The present visible ore-reserves are said to be small. Power is supplied from the Hosoo hydro-electric power-plant 12 miles distant, which develops 20,000 h.p. Production has increased from 6,315 tons of copper in 1907 to 10,428 tons in 1913, and 14,816 tons in 1916. The cost is probably less than £46 10s. per ton of metal.

The Ani group of copper mines is situated at Ani, on the west side of the Moriyoshi mountain, in Akita province. The group consists of the Kosawa, Kayakusa, Maki, Sammai and Ichinomata mines. Two systems of veins traverse a complex of Tertiary sediments, rhyolite and andesite. The principal metallic minerals are chalcopyrite associated with pyrite, and small quantities of galena and zinc-blende. The gangue is mainly quartz, but occasionally calcite and barytes also occur. The oxidized zone is deep. As in the Ashio mines, the main levels and shafts are equipped with electric locomotives and hoists, power for these, and for pumping and other purposes,

being derived from the Hosoo hydro-electric power-plant. There are three concentration mills at Honzan at the mouths of the Ariki, Kotaki and Tsudo adits. The crude mineral is hand-sorted into 12 per cent. and 0.8 per cent. copper ore, the daily output of crude ore being 250 long tons of the first grade, and 1,500 tons of the second. The latter is treated by jigs, tables and the flotation process. The Kosawa and Sammai mines have been extensively developed and are equipped with a concentration mill at Kosawa (containing Hancock jigs, tables and flotation plant) in which crude ore, containing 1 per cent. copper, is concentrated to a product averaging about 10 per cent. copper and 40 per cent. silica. About 16,000 tons of dressed ore are smelted annually, yielding about 1,500 tons of blister containing 98 per cent. copper and  $29\frac{1}{2}$  oz. silver per ton, which is refined at Nikko. Cement copper is recovered from old workings and dumps,  $2\frac{1}{2}$  tons of 66 per cent. copper being produced daily, and sent to the reduction works. The smelter at Honzan treats about 105,000 tons of 12.5 per cent. ore annually, and is equipped with smelting and converting plant. The blister copper produced averages: copper, 99 per cent.; gold, 1.6 dwt.; and silver, 28 oz. 12 dwt. per ton. The converters produce about 45 tons of blister copper daily, which is cast into 70-lb. anode plates, and sent to the Nikko copper refinery.

The Nagamatsu copper mines are situated on the south of Mount Gassan in Yamagata province. The ore deposits occur in veins traversing Tertiary shale, tuff and sandstones, with extensive intrusions of rhyolite and andesite. The metallic minerals are chiefly chalcopyrite and pyrite interbedded in clay, zinc-blende and galena occurring in some cases, with a little quartz and occasionally barytes. The deposit has been driven upon for 5,000 feet in the lowest level. Crude 1 per cent. copper ore is hand-sorted and concentrated mechanically up to 8.5 per cent. grade. The blister produced, which contains about 97 per cent. copper, and nearly 50 oz. silver per ton, is sent to Nikko for refining. The annual production of these mines is about 1,000 tons of copper.

The Mizusawa copper mines are situated at Iwasaki-mura, in Iwate province, the lodes occurring usually in granite. The principal metallic minerals are chalcopyrite and pyrite, galena and zinc occurring in small quantities. The gangue is quartz, but is not abundant. The most important lode, the "Machi," on which a considerable amount of work has been done, has an average width of 3 feet, and a length of 2,000 feet. The ore is mechanically concentrated, all the machinery being electrically driven. The crude ore contains 1.2 per cent. copper and the concentrates 7.4 per cent. The annual production of blister copper is about 500 tons.

The Otori copper mines are situated at Oizumi-mura in Yamagata province. The veins traverse a Tertiary tuff agglomerate and rhyolite. The main vein varies in width from 12 inches to 6 feet, and has a length of 2,500 feet. The metallic minerals

are chalcopyrite and pyrite, the gangue being quartz and rhodochrosite in small quantity. The crude ore contains 3.6 per cent. and the concentrates 8 per cent. of copper. The annual production of blister copper is about 500 tons.

The Kawaiyama mines lie 20 miles north-west of Yamaguchi. The deposit is of the contact metamorphic type, lying on both sides of a quartz-porphry dyke, erupted through Palæozoic limestone. It varies in thickness from 12 inches to 30 feet, and consists of an agglomerate of granite, hedenbergite (calcium-iron pyroxene), quartz, and chalcopyrite, some zinc-blende and galena being occasionally present. The longest level measures 2,500 feet. The blister produced contains 95 per cent. copper, with from 160 to 190 oz. of silver per ton, and amounts to about 500 tons per annum.

The Kune copper mines are situated at Saguma-mura, on the eastern bank of the river Tenryū. The deposit consists of beds of pyritic ore carrying from 3 to 8 per cent. of copper in a graphitic and chloritic schist. There are six ore-bodies, the largest of which is from 45 to 100 feet in width and 1,500 feet in length, and has been proved to a depth of about 1,500 feet. The ore is pyrite and chalcopyrite with some pyrrhotite. Quartz is sometimes found and magnetite occurs occasionally in separate layers. The mines have been developed by 14 levels, and produce both basic (pyritic) copper ore and siliceous ore, as well as a small quantity of cement copper (precipitated from the mine water by scrap iron). The annual production of copper ore amounts to about 170,000 tons, averaging 4 per cent. of copper.

The Furokura copper mines are situated at Oyu-mura, in Akita province. Quartz veins traverse Tertiary tuff, shale and andesite, the width varying from 12 inches to 12 feet, and the length being about 5,000 feet. The ore consists of chalcopyrite and pyrite. The high-grade ores are sorted by hand and the low-grade ores are washed and concentrated, the products, averaging  $5\frac{1}{2}$  per cent. copper, being delivered to the Kosaka smelter by ropeway. The annual production is about 50,000 tons of copper ore, yielding about 1,000 tons of metal.

The Mizushima smelter, which treats custom ores, is situated on the island of Mizushima, near Okayama. Blister copper produced, amounting to about 3,500 tons per annum, is sent to Nikko for refining.

The Nikko copper works are situated at Kiyotaki, between Ashio and Nikko. Here the Bessemer copper from Ashio, and the blister copper from the other mines owned by the Furukawa Mining Company, containing bullion, are refined electrolytically, while blister copper free from precious metals is refined in reverberatory furnaces. About  $1\frac{1}{2}$  million oz. of bullion is recovered.

The Honjo copper works are situated at Yanagiwara-cho, Tokyo. The annual production of copper and brass sheets amounts to about 500 tons.

The Amagasaki refinery, situated near Osaka, has an annual production of about 5,000 tons of refined copper, 2,000 tons of lead, and 10,000 oz. of silver bullion.

The Kuhara Mining Company owns copper, gold and silver mines, such as the Hitachi in Japan and the Kapsan mine in Korea, also refineries at Saganoseki and Tyejuna. Its annual production is from 2,500 to 3,000 tons of electrolytic copper, 9,000 to 10,000 oz. gold, 120,000 to 150,000 oz. silver, and 75 to 100 tons of copper sulphate.

The Hitachi mine is situated 5 miles north-west of Sukegawa, between Tokyo and Sendai. The deposits consist of lenticular masses interbedded with amphibolites. There are five principal beds, of which the largest is the Chusei, 1,230 feet long and 21 feet wide. The ore consists of cupreous pyrites varying from 2.2 to 2½ per cent. copper and containing small quantities of gold and silver. Pyritic smelting is adopted, the matte obtained being converted to blister which is refined electrolytically. The annual production is about 15,000 tons of copper.

The Mitsubishi Company is the principal mining and metallurgical enterprise in Japan. The Company's products include gold, silver, copper, tin, tungsten ore and coal. In 1916 the metal mines yielded 13,670 tons of copper, 45,760 oz. of gold, and 883,360 oz. of silver; and in 1918, 7,167 tons of copper, 22,958 oz. of gold and 475,481 oz. of silver.

The Osarusawa mine situated in the Kazuno district, Akita, 10 miles south of the Kosaka mine, is owned by the Mitsubishi Company. It was formerly worked for gold only. The ore occurs in a complicated interlacing system of fissure veins, traversing Tertiary shales and tuffs intruded by andesite and rhyolite, and varying in width from less than 12 inches to more than 10 feet, averaging 3 feet. The ore, which averages from 3 to 4 per cent. of copper, consists of chalcocite, chalcopyrite, bornite and a little native copper, associated with a large amount of pyrite and small quantities of zinc-blende, galena and hæmatite. The gangue is chiefly quartz and chlorite. The ore is smelted and converted to blister copper which is sent to the Osaka electrolytic refinery. The production of ore averages 16,700 tons monthly, and the annual production of copper is about 3,000 tons.

The Arakawa mine is situated in the Sempoku district, Akita province. The country rocks are Tertiary volcanic sediments and crystalline rocks, including andesites and rhyolite. There are 10 parallel veins which have been worked from 1,000 feet to 4,000 feet along the strike, the deepest working being 800 feet in the lowest adit. The ore consists of chalcopyrite and quartz, with a little pyrite, galena and blende. Oxidized ores mixed with sulphides, averaging about 2 per cent. copper, extend to 500 feet below surface. Production amounts to 5,000 tons of ore per month, and about 1,500 tons of copper per annum.

The Hisaichi mine is situated at Nakagawa, 5 miles south-east of Arakawa, and the geological conditions are similar. There are 7 veins. The largest has an average width of about 24 feet



of which about 8 feet is payable. The other workable veins range in width from 5 feet to 7 feet. The ore averages 3 per cent. copper as chalcopyrite with oxides of copper, hæmatite, galena and blende, and a little gold and silver. The mine has been developed to a depth of 500 feet, the annual production of ore being about 24,000 tons. A part of this is smelted locally.

The Omodani mine is situated at Kamianama, Ono district, Fukui province, 27 miles from Ono-machi. The property was opened in the 14th century. The deposits worked include numerous small veins, not exceeding 3 feet in width, impregnating sandstone and altered quartz-porphyry, the ores consisting of bornite, chalcopyrite, zinc-blende and galena, all argentiferous, while native silver also occurs. Four larger veins, up to 10 feet in width and containing low-grade ore, are also worked. The ores average about 6 per cent. copper and 72 oz. silver per ton and the annual production of ore is about 46,500 tons.

The Ikuno mines are situated at Ikuno, Hyogo province, Western Honshu. The principal mines of this group are the Tasei, Kanagase, Akenobe and Kasei. The Tasei main vein is 14 feet in width, and has numerous branches, the country rock being quartz-porphyry. The ore consists of various sulphides (chalcopyrite, galena, zinc-blende and pyrite) and has a high silver content. The production, in 1918, was 2,201 tons of copper, 168,147 oz. of silver and 2,007 oz. of gold.

At the Kanagase mine three veins are worked in quartz-trachyte. Fault-dislocations occur along several andesite dykes traversing the property. The chief copper vein is from 8 to 10 feet in width and 10,000 feet in length, the ore consisting of bornite, chalcopyrite, tetrahedrite, blende, galena and pyrite, with which stannite and bismuth ores are sometimes associated. Two other veins, from 3 to 9 feet in thickness and about 2,000 feet in length, contain argentite, blende, galena, ruby silver and stibnite, in addition to copper sulphides. The production is about 500 tons of copper per annum.

The Akenobe mine has numerous copper and tin-bearing veins in Palæozoic slate, eleven of which, varying in width from 3 feet to 4 feet, have been worked. The ores consist of chalcopyrite, bornite, cassiterite, wolframite and blende.

The country rock of the Kasei mine is hornblende-gneiss intersected by rhyolite and porphyry dykes, the ore-deposits consisting of fissure veins containing silver sulphides, associated with chalcopyrite and native silver. The copper produced averages about 97 per cent. copper,  $4\frac{1}{2}$  oz. gold and 155 oz. silver per ton.

The output in recent years has averaged about 2,100 tons of copper, 2,500 oz. of gold and 250,000 oz. of silver per annum.

The Yoshioka mine is situated at Fukiya, in the Okayama province, Honshu. The country rocks are slates, sandstones and phyllites, intersected by porphyry and quartz-porphyry dykes. The ore deposits occur in sedimentary beds, and as impregnations in the slate, in an igneous contact zone. The former class form a stockwork. The ore is chiefly chalcopyrite with some pyrite, arsenopyrite, pyrrhotite, galena and blende in a quartz gangue, and averages 3 to 8 per cent. copper. The output of ore amounts

to about 7,000 tons per annum, and the production in recent years has been about 700 tons of copper, 130 oz. of gold and 60,000 oz. of silver.

The Makimine mine is situated at Kitakata, Miyazaki province, Kiushiu. The country rock is slate, with interbedded sandstones, and a capping of lava. The slate is intersected by small veins carrying lenticular bodies of pyrite, averaging 5 per cent. copper. There are eleven main veins, with ore-bodies from 10 to 20 feet in width, and from 30 to 300 feet in length. The mine has been developed to a depth of 1,000 feet. The production in recent years has been from 700 to 1,000 tons of copper per annum with about 1 oz. gold and 10 oz. silver per ton of copper.

The metallurgical works of the Mitsubishi Company at Osaka include reverberatory furnaces, which produce anodes of 97 to 99 per cent. purity for conversion into electrolytic copper. This assays 99.89 per cent. copper. The output in recent years has been about 17,000 tons of copper, 70,000 oz. of gold and nearly 1 million oz. of silver per annum.

The Sumitomo Copper Company owns the Besshi copper mine, on Besshi Mountain, Iyo Province, Shikoku, the Nishinokawa mine, in the same province, and a smelter and refinery on Shisakajima, a small island off the coast.

The Besshi mine is the chief representative of the so-called bedded type in Japan. From its discovery in 1690 it is reported to have produced nearly 2 million tons of ore, and the reserves still remaining are said to be too large to be estimated. Two-and-a-half million tons are blocked out at present. The deposit is embedded in crystalline schists which form the watershed range of the island of Shikoku, rising to 4,000 feet above sea-level. The ore-body, which is over 5,000 feet in length, and from 2 to 30 feet (averaging about 7 feet) in width, has been explored to a depth of more than 3,000 feet measured along the dip. It consists of three classes of ore: (1) massive pyrite, containing about 3 per cent. copper and 2 per cent. silica; and (2) banded pyrite, containing about 4 per cent. copper and 3 per cent. silica; and (3) massive chalcopyrite with a certain amount of gangue. The ore is hand-sorted at surface and is not mechanically dressed. The average smelting ore contains about 4 per cent. copper. It is reported that  $2\frac{1}{2}$  million tons of ore are blocked out ready for stopping. The mine water, which amounts to about 40 cubic feet per minute, yields about 35 tons of precipitate (50 per cent. copper) per month. The water leaving this plant is further dealt with, scrap iron and coke being used as precipitants, and an additional 50 tons of precipitate, containing 8 per cent. of copper, is recovered in this way monthly. The precipitate is sent to the smelter and refinery at Shisaka.

The Nishinokawa mine at Oboki contains lenses of ore, from 3 feet to 12 feet in width, in quartz-schist. The ore consists of chalcopyrite, containing from 3 to 4 per cent. of copper, associated with blende, pyrite, magnetite and hæmatite in a quartz gangue. The ore is concentrated in a mill of 700 tons daily capacity, and a cementation plant has been installed which produces 200 tons annually of 80 per cent. copper precipitate from the mine waters.

The smelting plant on Shisaka Island is fully equipped. The blister copper produced contains 99·8 per cent. copper with traces only of gold and silver. The smelter treats 600 tons of ore daily, the ore containing from 30 to 33 per cent. of sulphur. The production of the Besshi mine is understood to be from 8,930 tons to 10,130 tons of copper annually, costing about £44 per ton.

The right to work mines in Japan is granted to individuals and companies of Japanese nationality, and their ownership is concentrated in a few hands. The Japanese producers sell their own copper, all foreign agencies being strictly Japanese. The mines in Japan are not generally worked as joint stock enterprises, but are chiefly exploited by families who have inherited them.

*Japanese Production, Imports and Exports of Copper*  
(Statistical Reports of the Department of Agriculture and Commerce, Japan, Annual)

Year.	Production Quantity (long tons)	Imports* Quantity (long tons)	Exports† Quantity (long tons)
1913 ... ..	65,314		41,922
1914 ... ..	69,205	32	45,107
1915 ... ..	74,069	797	58,666
1916 ... ..	98,838	3,057	61,673
1917 ... ..	106,109	5,466	77,392
1918 ... ..	88,728	865	40,515
1919 ... ..	77,042	27,409	23,871

\* Including ingots, slabs, waste, &c.

† Including ingots, slabs, plates, sheets, wire, bars, rods and tubes.

### Korea\*

The richest and most extensive deposits of copper ore hitherto discovered in Korea occur at Kapsan, in South Kankyo province, in the north-east. Another mine is situated in the Huchang district (Kosho), in the extreme north of the peninsula, near the upper waters of Yalu river, and important deposits have been found in South Chusei province, in the south. The production of copper ore in Korea has not yet reached very considerable importance.

At Kapsan the ore developed amounted to 168,000 tons, averaging 10½ per cent. copper in 1916, when the mine was sold to the Kuhara Mining Company, Ltd., the owner of the Hitachi mine in Japan. In 1917, the smelter was reported to be treating 200 tons of ore daily.

The Seoul Mining Company, an American undertaking, has for about 12 years been exploiting an auriferous copper-ore deposit on a concession situated in the Suan district, Province of Whang Hai, about 50 miles by road east of the city of Pyeng Yang. This concession was granted by the Korean Government in 1905

\* Min. Sci. Press, 1919, Oct. 11. Mines Handbook, Weed. Annual Statistical Reports of the Department of Agriculture and Commerce, Japan.

to the Korean Syndicate, Ltd. (a British company), which receives a percentage of the profits made by the operating company. The Suan concession covers an area of approximately 20 by 13 miles, within which it owns exclusive mineral rights. The principal ore-bodies occur in limestone (largely magnesian) near its contact with a granite batholith which has uplifted and pushed aside the overlying series of slates and limestone. The ore-bodies occur as irregular tabular or lenticular masses, connected generally by fairly well defined fissures, and running around the contact, which is roughly an elliptical ring with axes about 7 miles and 9 miles in length, respectively. The mineralized ore-zone (known as the "Collbran Contact") has a length of about 20 miles, and the ore-deposits are rarely at a greater distance than 200 feet from the granite. The lenticular masses in the Suan mine have varied in width from a few inches to more than one hundred feet, and have been followed for a length of about 1,000 feet, measured along the pitch. The ore-bodies of the Suan and Tul Mi Chung mines are mainly characterized by the presence of gold, copper and silver. Pyrite and sulphides of arsenic accompany chalcopyrite, in a quartz gangue containing many contact metamorphic minerals and a considerable quantity of garnet. The Suan mine is said to be now nearly exhausted. The ore has been treated by amalgamation followed by concentration and flotation, which was adopted in 1914. The concentrates have been exported to England and the United States for the recovery of their gold, copper and bismuth content. The ore milled has varied in annual average value from about 9 dwt. to 13 dwt. gold per short ton (2,000 lb.), and from about 1 to  $1\frac{1}{2}$  per cent. copper, with about  $1\frac{1}{2}$  lb. of bismuth per ton.

The Tul Mi Chung mine, situated about 6 miles in a direct line from the Suan mine, and on the same contact, was first opened up in 1912, and is now the principal mine on the concession. At this mine ore also occurs between limestone and schist. The mill has a daily capacity of about 500 short tons of gold-copper ore, the works including flotation and cyanide plants.

In 1919, the ore crushed at the Suan and Tul Mi Chung mines amounted to 146,433 short tons, the average value of which was about 37s. 6d. per ton. The total ore reserves were estimated to be about 650,000 tons, value 37s. 10d. per ton. The working costs averaged less than 19s. per ton during the period under review.

The Tong Ahm mine, situated about  $1\frac{1}{4}$  mile to the north-west of Tul Mi Chung, is being developed with promising results, more than 50,000 short tons of gold-copper ore, with an average value of 37s. 7d. per ton, having been developed during the period under review.

At Soctarie, near the site of the Suan mill, a bedded deposit of great extent, containing gold, copper and tungsten, is being developed. The ore occurs in large lenticular masses in silicified limestone. The grade is low, the main value consisting of tungsten (in the form of scheelite), the percentage of tungstic acid ( $\text{WO}_3$ ) being only about C.

*Production of Copper Ore and Crude Copper in Korea*  
(Statistical Reports of the Department of Agriculture and  
Commerce, Japan, Annual)

Year	Copper Ore Quantity (long tons)		Copper Quantity (long tons)
1913	...	50	2
1914	...	7	2
1915	...	4	—
1916	...	126	—
1917	...	298	2,200
1918	...	248	3,050
1919	...	...	

**Siberia and Turkestan\***

*Siberia*—Deposits of copper ore are abundant in the Kirghiz Steppes (south-western Siberia) and in the Altai region (Tomsk Government), while many deposits are known in the Yenisei Government, and discoveries have been made also in the Irkutsk Government, in the Transbaikai, and in Kamchatka.

*Altai district.*—Copper-mining began in this region early in the 18th century, and many rich deposits have been found, especially in the Zmeinogorsk district, but the only mines that have been worked in the Altai in recent years on an important scale are those of the extensive Zmeinogorsk, Ridder and Zyrianovsk concessions, which are controlled by British companies. These concessions are bounded on the west by the headwaters of the Irtysh river.

The Byelousovsk copper mine is situated on a well-defined copper belt running through the Zmeinogorsk concession, the region being one of tilted Devonian and Carboniferous sedimentary rocks, mostly graywacke, slate, tuff, and limestone, intruded by various igneous rocks. On this old property, which had been abandoned after many years of productivity, diamond-drilling is stated to have shown the existence, beyond and below the old workings, of an ore-body with a length, so far as at present determined, of about 3,000 feet, and an average thickness of between 15 and 20 feet, from  $1\frac{1}{2}$  to 2 million tons of ore, with an average content of fully  $3\frac{1}{2}$  per cent. copper and about 9 per cent. zinc, being indicated. Towards the end of 1918 it was reported that drilling to the north of the Byelousovsk mine had indicated the existence of a large body of high-grade copper ore.

The Ridder and Sokolni mines, situated on the Ridder concession, which lies between the two other concessions mentioned above, are being developed with apparently promising results. The Ridder mine was worked from 1778 to 1863, when complex sulphides were encountered. The ore-body, which has a slate

\* S. H. Ball and B. Low, Eng. Min. Journ., 1917, Vol. 103, 406-417. W. H. Weed, The Copper Mines of the World. The Mineral Industry (Annual). Official Reports.

hanging-wall and a footwall of hornstone (contact metamorphosed shale), is at least 750 feet in length, averages 36 feet in width, and has a known depth of more than 700 feet measured on the incline. The sulphides occurring in the ore-body are blende, galena, pyrite and chalcopyrite. In the middle of 1917, when political conditions forced a stoppage of practically all operations on the property, the ore-reserves of the Ridder and Sokolni mines were reported to be as follows:—

	Ore-reserve Quantity (tons)	Content				
		Gold (oz. per ton)	Silver (oz. per ton)	Copper (per cent.)	Lead (per cent.)	Zinc (per cent.)
Ridder (solid sulphide).	945,000	0·47	9·7	1·5	18·1	31·2
Sokolni (solid sulphide).	360,000	Substantially the same grade.				
Ridder (concentrating ore).	2,229,000	0·71	1·7	0·5	3·5	6·7

A concentrating mill was started in 1915, and several thousand tons of zinc and lead concentrates were produced before operations were suspended. These concentrates were shipped for treatment to Ekibastus, where the company owns large collieries. Up to the present time no production of copper appears to have been reported.

Other copper ore-bodies have been found on the concession.

Copper-mining is also being carried on in the Altai at the Sugatovsk and Tchudon (Tschoudak) mines, in the systems of the Uba, an affluent of the Irtysh, the ore-body at the latter mine being more than 20 feet in thickness, and carrying chalcopyrite in a quartz gangue.

*Kirghiz Steppes.*—Deposits of copper ore, many of which outcrop, occur in great abundance in this region, more particularly in the south-eastern part of the Akmolinsk district, in the southern part of Pavlodar district (on the Irtysh River, in the Semipalatinsk territory), and in the Karkaralinsk district (Semipalatinsk). At least 200 outcrops have been located in the region, mostly in the last-mentioned district. The copper content of the ores is generally less than 10 per cent. It is expected that the region will become a very important producer of the metal when the projected railway lines have been constructed, the principal mines being situated near coal supplies and labour being normally abundant and cheap. The only important copper mines so far developed in the Kirghiz Steppes are those of the Spassky Copper Mine, Ltd., the principal mine on that company's property being the Yuspenssky, which is situated about 500 miles south of Petropavlovsk, a station on the Trans-Siberian Railway, and about 150 miles south of Akmolinsk. In this mine, slate and arkose sandstone of Permian age are folded into an arc,

an ore-body occurring along the contact at each end. The main ore-body is 250 feet in length and 30 feet in width, while the smaller is about 120 feet in length and 30 feet in width. A band of massive chalcocite and bornite, assaying 20 per cent. copper, lies against the slate hanging-wall, the vein becoming gradually poorer towards the footwall, and grading into copper-impregnated sandstones. The reserves were estimated in 1905 at 180,000 tons of ore averaging  $18\frac{1}{2}$  per cent. copper. By 1913, the shaft had reached a depth of 630 feet, and further sinking was in progress. In 1915 it was officially reported that the ore had been gradually changing in character and copper-content in the deeper levels, chalcopyrite taking the place of bornite and the ore being more evenly disseminated through the gangue; also that in future the production of copper must be looked for from reserves averaging about 8 per cent. copper. The lowest level at that date was about 700 feet below the surface. In June, 1919, the ore-reserves were estimated at 419,800 tons, averaging 7·8 per cent. copper.

The Spassky smelter is capable of producing about 400 tons of copper per month. The production during the period under review was as follows :—

Year	Copper produced (tons)		
1912-13 (15 months)	...	...	6,251
1914	...	...	4,683
1915	...	...	3,450
1916*	...	...	—
1917†	...	...	1,467

The construction of the projected South Siberian Railway from Orenburg to Semipalatinsk, passing through Akmolinsk, is expected to stimulate the production of this mine.

The company owns the Karagandy and the Saran coal mines, which are connected with the Spassky smelter by a railway 26 miles in length, the reserves of the Karagandy mine being stated to exceed 400 million tons. In 1913 the company acquired the property of the Atbasar Copper Fields, Ltd., about 250 miles north-east of Djousalie, a station on the Orenburg-Taskent Railway. The reserves at the Atbasar mines were estimated late in 1915 at 543,900 tons, averaging 13·1 per cent. copper, with from 35 to 50 oz. of silver per ton of copper. A narrow-gauge railway has been constructed from these mines to a coal mine, about 80 miles distant, owned by the company, and a line is being constructed to connect Atbasar with a smelter in course of erection at Karsak Pai Zavod, midway between the copper mines and the coal property. This smelter will be capable of producing 6,500 tons of copper per annum.

In *Turkestan* several copper deposits are known, but only one attempt has been made at development, and this without success.

In *Eastern Siberia* many deposits of copper ore have been found in the Yenisei Government, in the Minusinsk region and other districts. In the Transbaikal district copper ore has been dis-

\* Smelter shut down for practically the whole of the year.

† In 1917, as also in 1918, the smelter was operated only intermittently.

covered in the basin of the Tchikoi and along the Khilok river. Copper ore has also been found in the Maritime province (Primorsk), the peninsula of Kamchatka, and elsewhere in Siberia.

### Java\*

Copper is found chiefly in Madiun, and occurs in the Preanger highlands, but it is not believed to exist in large quantities anywhere.

In the Poelonz district, near Soerabaya, a body of mineral, carrying fair values in auriferous and argentiferous chalcopyrite, sphalerite and galena, was opened up in 1903, the ore carrying 0·9 to 5·25 per cent. of copper in a vein about 6 feet in average width.

In the Gunong Kendang district there are thermal springs carrying copper iodides in solution, from which iodide of copper is obtained by evaporation, the production amounting to 5,172 lb. in 1899.

### Dutch Timor†

Rich deposits of copper ore were reported, in 1920, to have been discovered in South Timor, near Janinj, a village 20 miles from Tjamplong and 50 miles from Koepang. Extensive development work has been carried out by the Geological Department of the Dutch Government, but it was stated recently that the results had not proved satisfactory.

### New Caledonia‡

A considerable amount of copper has been obtained from the mines of Pilou, Balade, Ao and others situated in the north of this island, in the neighbourhood of the port of Pam and the Dihot river. The ore occurs in veins and lenses and as stockworks in talcose and chloritic schists. The oxidized ores near the surface, principally carbonates, contained from 1·3 to 2·6 dwt. of gold per ton, whilst the selected sulphide ores, principally chalcopyrite with some galena and a little blende, contained from 6 to 13 oz. of silver per ton.

In 1902 the output of copper ore amounted to 3,661 tons, and the highest production of the district was reached in 1899 when 6,247 tons, valued at £492,310, were produced. No production is recorded for the period under review.

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\* British Foreign Office Historical Handbook, 1920. No. 82.

† Information supplied by the Dept. of Overseas Trade; Board of Trade Journal.

‡ British Foreign Office Historical Handbook, 1920, No. 86. *Les Mines de la N. Calédonie*; *Genie Civil*, 84, p. 1892. *The Mineral Resources of New Caledonia*; *Trans. Inst. Min. Met.*, 1900. *The Copper Lodes of New Caledonia*; *Trans. Aust. Inst. Min. Eng.*, 1901. *Richesse Minérale de la N. Calédonie*; *Ann. des Mines*, 1903-4.



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